THE HAYNES FOUNDATION

War and Postwar Developments in the Southern California Petroleum Industry

BY JOE S. BAIN

WAR AND POSTWAR DEVELOPMENTS

in the

SOUTHERN CALIFORNIA PETROLEUM INDUSTRY

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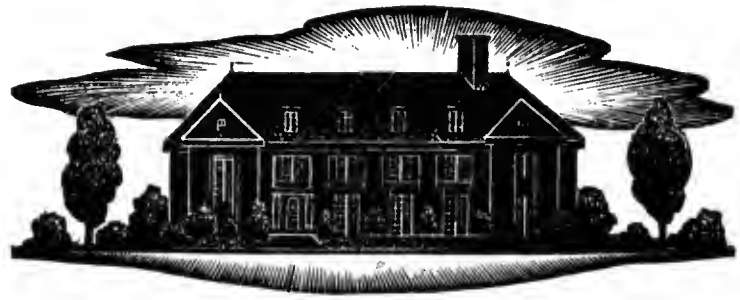

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TABLE OF CONTENTS

WAR AND POSTWAR DEVELOPMENTS
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INTRODUCTION

As the end of the European war appears to be in sight and as plans for human demobilization and industrial reconversion increasingly demand our attention, we must legitimately be concerned more and more with the prospect for postwar employment and prosperity. The problem is particularly severe in Southern California, where the impact of the general shift to a wartime economy has been felt with great intensity. During the war period the economy of the Los Angeles basin has become heavily specialized in munitions industries; its industrial activity has expanded greatly; and it has, in spite of a loss of prewar population to the armed forces, experienced a ten per cent net gain in civilian population. There is consequently posed a grave problem as to how the reconversion period will affect the Southern California economy. Can the present rate of industrial activity be maintained? Can employment be provided both for the presently expanded civilian population and for the returning service personnel? Is the area prepared to advance industrially toward new and higher goals? These are only a few of the questions requiring immediate attention.

Full analysis of these problems must of necessity undertake simultaneous consideration of the whole varied and complex economy of the area, and adequate answers can emerge only from such an analysis. It may nevertheless be helpful as an adjunct to this broad effort to undertake certain narrower investigations of various strategic segments of the economy, a detailed understanding of which may enable us better to deal with the larger issues posed.

A sector of the Southern California economy which demands primary attention from this standpoint is the petroleum industry. As the fundamental fuel-supplying industry of the area, it merits detailed consideration, for the conditions which prevail within this industry will have a very important impact on the total welfare of the economy which it supports.

CHAPTER I

THE PLACE OF PETROLEUM IN THE ECONOMY OF SOUTHERN CALIFORNIA

Before the present war, the petroleum industry occupied a position of great importance in the Southern California economy. First, it directly employed about 15,000 workers in producing and refining crude oil, and many more in marketing.[1] The Los Angeles basin was producing from 90 million to 135 million barrels of crude oil a year, with an annual value of from 100 to 150 million dollars.[2] Los Angeles refineries, processing the bulk of this crude oil together with substantial additional amounts brought in from other parts of the state, had a gross output valued at about 225 million dollars a year.[3] A good deal of employment and income was also provided by the auxiliary industries which supplied materials and equipment for primary petroleum production and for refining, and by the large natural-gas industry, which distributed this important by-product for use as a domestic and industrial fuel.

The full importance of the petroleum industry to the Los Angeles area, however, is not revealed by these measures of its employment, output, and value-product. For although it was directly responsible for a moderate proportion of the industrial and commercial activity of the area, it was the indirect source of a much larger proportion of this activity. Many types of industrial production can be economically undertaken only in areas where there is a cheap supply of bulk fuel to provide inexpensive heat and power. The rise of petroleum production in Southern California has provided an abundant and low-cost supply of fuel oil and natural gas, and the availability of these has evidently in turn played an important role in attracting industrial plants to locate and remain in the area. The large supply of petroleum products was similarly essential to the maintenance of a vigorous transportation industry. California steam railroads have depended almost entirely for locomotive boiler fuel upon the residual fuel oil from California refineries; the trucking and passenger-bus industries have drawn heavily upon local supplies of gasoline and Diesel fuel; and coastwise and ocean shipping have been attracted by the large available supply of bunker fuel. Finally, the importance of Los Angeles as an ocean port has depended very strongly upon the fact that Southern California is an oil producing and refining center. A large portion of the total volume of exports from Los Angeles harbor has normally been made up of crude petroleum and refined petroleum products.

It is thus perhaps instructive to consider the hypothesis that in the prewar period Los Angeles was in an important degree an oil town, and that the Southern California economy was an oil economy. The area of course had

1 From data collected by the Haynes Foundation, Los Angeles
2 Petroleum World Annual Review, 1943, pp 129, 273-279. Calculated.
3 Ibid.

other basic resources which tend to attract population and industry--notably its climate, its coastal location, and its agricultural hinterland. Allowing for those factors, however, oil seems to have been strategic to the industrial development of Southern California and to have contributed substantially to its economic ability to support a large population. The fact that the period of greatest population growth in Los Angeles succeeded the development of large oil deposits in the Los Angeles basin in the early 1920's is not to be regarded as entirely coincidental.

The economic past of the area has thus been closely linked with the development of its petroleum industry, and its present economic structure is strongly dependent on oil. This does not imply that progress has not been made toward diversification of industry and an increasing degree of independence from the petroleum industry, nor that further progress may not be made. The Southern California area has become the locus for an increasing amount of secondary industry which is not primarily dependent on cheap fuel. Furthermore, the introduction of relatively cheap hydroelectric power from the Boulder Dam project has provided an important alternative source of energy. But the economy of the Los Angeles basin is still sufficiently dependent upon oil that the activity of its petroleum industry is of very great significance.

During the present war period, this significance may have been somewhat obscured. The Southern California area has become a principal center of war production, with an expansion of industrial output sufficient to induce considerable additions to an already large labor supply. Aircraft construction and shipbuilding dominate the current industrial scene and considerably exceed even the petroleum industry in immediate size. But apart from the fact that the area's ability to attract these industries depends in some part upon its fuel supplies, it must be emphasized that they are primarily munitions industries and that as a consequence a large proportion of the demand for their production will inevitably dry up with the cessation of hostilities. Looking toward the postwar period, therefore, we must recognize that although Southern California will presumably have a somewhat larger aircraft industry than it did in 1939, its economy will no longer be dominated by the present war industries, and that the relation of its economy to petroleum will be substantially what it was before the outbreak of the global war.

The future of the Southern California petroleum industry is thus a matter of substantial concern to every individual and business interest in the area. Industries are seldom stable over time. They rise or decline, suffer gluts and shortages, experience technical revolutions or merely the slow evolution of technique. Industries which are primarily engaged in or dependent upon the extraction of exhaustible natural resources--and the petroleum industry is one of these--are particularly susceptible to change. They live always on borrowed time, awaiting decline and eventual extinction when their raw materials become scarce and are finally exhausted; meanwhile they prolong their existence as far as possible through efforts to discover new resources and by searching for technical developments which will allow them to use available resources more efficiently. Continued change is thus to be anticipated in any petroleum industry, including that of Southern California. The probable future path of its change is obviously a matter of some moment not only to the industry itself, but also to the economy which depends upon it.

The future of the Southern California petroleum industry was thus a significant matter for discussion even before the outbreak of the present war. It

may not, however, have appeared to be very pressing at that time. In the decade before 1940 California oil producers were primarily concerned with controlling the production and disposal of a considerable potential surplus of crude oil. This surplus had accumulated initially from discoveries during the 1920's, and had persisted as a large part of the crude oil produced and used between 1930 and 1940 was replaced by fortuitous new discoveries in the Los Angeles Basin and elsewhere in California.[4] The basic raw material supply, although intrinsically susceptible to exhaustion, was thus not threatened for a comfortably long future period--at least a decade--and it seemed likely that the ultimate exhaustion of petroleum deposits could be much further postponed through the discovery of new underground supplies. Technological progress in production and refining was steady but not disruptive in character. Refined products were plentiful and relatively cheap and promised to remain so for a long time. In brief, relative stability in the California oil industry over a moderately long future period could be anticipated or at least hoped for, and prognoses of fundamental change seemed to fall definitely in the category of long-run prediction.

The experiences of the war period have made the prognosis of fundamental change a more immediate problem. The war has had a number of important effects upon the Southern California petroleum industry. Some of these effects bear directly upon the preexisting problem of long-run change, and some create special short-run problems which would not otherwise have been encountered.

An important factor affecting the long-period future of the industry has been a marked acceleration in the rate of use of existing resources. The rate of depletion of known oil reserves has been temporarily increased by 40 or 50 per cent, and this has hastened their eventual exhaustion. Perhaps more important has been the limited success which has rewarded the efforts of the industry to expand its current rate of production and its discovered reserves. Faced by an acute oil shortage, the industry has expanded the production from known reserves to the economic limit in most fields, and its exploratory activity has greatly increased. The results on both counts have been disappointing. On one hand, it has been found that the maximum productive capacity of previously discovered reserves was somewhat smaller than many persons had previously estimated. On the other, exploratory activities have been rather poorly rewarded, yielding only small additional discoveries, and this supports the belief that it may not be possible to find large additional quantities of oil in California. The prospect for discovery looks especially poor within the Southern California area. As a consequence of the recent experience, estimates of future oil production in Southern California and in California as a whole have been revised downward, and the emergence of a chronic shortage of crude petroleum seems more imminent than ever before.

The immediate implications of the war development are of a different character. Under the pressure of war demand, the current productive capacity for both crude oil and refined products has been considerably expanded. In the immediate postwar period this capacity will presumably exceed total demand. The character of the buying market for refined products, moreover, has been drastically altered by the war, as the federal government has become a dominant purchaser, as civilian demand for gasoline has been curtailed by rationing, and as export shipments

4. See Joe S. Bain, Economics of the Pacific Coast Petroleum Industry: Part I, Market Structure, pp. 60-66 for an outline of the surplus problem in the prewar period, together with a brief description of the conservation and proration machinery.

have approached a vanishing point. Time will be required in the postwar period for a normal distribution of petroleum products to be restored. Finally, the war period has greatly stimulated technical change in refinery plants, undertaken primarily in order to enhance the production of aviation gasoline. The character of postwar production for civilian demand will be influenced by these technical changes, and corresponding market adjustments will be required. In short, wartime changes in the quantity and quality of productive capacity and in the structure of market demand presage a series of immediate postwar readjustments which should be considerable enough to merit some advance attention.

Anticipated short-run readjustments and long-run changes in the petroleum industry both require examination. The purpose of the present paper is to appraise the probable character of these readjustments and changes in the postwar period, and to evaluate their probable impact on the petroleum industry and the economy of Southern California. In the following discussion, this prognosis is necessarily prefaced first with a short appraisal of the prewar situation in the industry, and second with an examination of the developments in the war period to date. In the succeeding discussion of probable postwar developments, a distinction must be drawn among: 1) the immediate postwar reconversion and demobilization period, 2) the secondary postwar period, of from six to ten years, which follows reconversion, and 3) a longer period extending two to three decades after the war. The problems encountered in these various intervals promise to be quite different in character.

At the outset, however, a word of warning is perhaps in order. The petroleum industry is only one part of a complex and interrelated system of industries which make up the California or Southern California economy. Its position in this system is indeed strategic, in that it is the supplier of basic fuel products upon which other industries depend. But by the same token it is itself strongly dependent upon those industries for a demand for its products, and its ability to provide employment and income depends upon the level of activity in those industries. It follows that we cannot from an investigation of the petroleum industry obtain an adequate insight into postwar income and employment either in the industry alone or in the economy which it supports. What we can obtain is a prognosis of the manner in which conditions in the petroleum industry may <u>influence</u> the development of employment and income in the surrounding economy, and thereby contribute to postwar expansion. This limitation should be borne in mind in the succeeding analysis.

CHAPTER II

THE PREWAR SITUATION
in the
CALIFORNIA PETROLEUM INDUSTRY

As we turn to a description of the prewar status of the Southern California petroleum industry, it should be useful to indicate briefly its relationship to the industry in California and in the entire United States. The modern petroleum industry involves two basic processes--production and refining. Production involves the discovery of sub-surface pools of crude oil and the recovery of their contents through wells.[1] Refining consists of separating crude oil into its various components, reforming these components through chemical processes, and treating the end products to make them suitable for use, principally as fuels, but also as lubricants, chemical raw materials, etc.[2] These primary processes are necessarily facilitated and supplemented by important auxiliary activities, including crude-oil and refined-product transportation and wholesale and retail distribution of refined products.

The crude-oil producing division of the petroleum industry in the United States is located principally in the Midwest, in Texas and the Gulf Coast, in Wyoming, and in California.[3] The principal refining centers are located in part in these production areas, and also in a number of the large cities on the Atlantic seaboard and in the Great Lakes area. Distributive facilities, on the other hand, are less concentrated, being necessarily distributed throughout the country in rough proportion to the population.

California is thus one of the principal loci for both the producing and the refining industry of the country, as well as supporting connected transport and distributive facilities. In 1940 about 17 per cent of the national industry was located within this state, which accounted for from 16 to 18 per cent of the discovered reserve of crude petroleum,[4] 16½ per cent of the crude oil production,[5] and 17 per cent of the basic capacity for refining.[6] The natural domestic market area of the California industry comprised the five western states of California, Washington, Oregon, Arizona, and Nevada, and almost all of the refined products used in these states were of California origin.[7] In addition, however, California continually produced a substantial surplus for export. In the later 1930's it exported about 25 per cent of the original volume of its crude output.[8] About a third of this was exported as crude oil and the remainder as refined products, principally

1 See Bain, op. cit., pp. 38-42 for a brief non-technical discussion of the technique of crude oil production.
2 See ibid., pp. 84-102 for a brief description and explanation of the principal refinery processes.
3 Bain, op. cit., pp. 14-15
4 See e.g. U.S. Congress, Hearings, on H. R. 58, 78th Congress, Supplement, Apr.-Dec., 1943, p. 38; Oil and Gas Journal, April 1, 1943; and Office of Petroleum Coordinator, Heavy Oil Survey of State of California, (Los Angeles, 1942) Table 1.
5 Petroleum World Annual Review, 1941, p. 62.
6 Bureau of Mines.
7 See Bain, op. cit., pp. 20-22.
8 Ibid., p. 175.

gasoline and fuel oil. In latter years, western Pacific buyers (largely Japanese) took about 70 per cent of the volume of California exports, Pacific possessions about 15 per cent, the Atlantic Coast about 10 per cent, and overland states and foreign buyers the remainder.[9] California was thus a surplus production area which was always easily able to oversupply its maximum domestic needs.

The California producing and refining industry is concentrated in the southern half of the state, and principally in the Los Angeles area. Crude oil is produced in California in the Los Angeles basin, in the San Joaquin Valley, and in the coastal region from the vicinity of Santa Barbara to the neighborhood of Santa Maria. In 1940 the Los Angeles basin supplied 48 per cent of the crude production of the state, the San Joaquin Valley 39 per cent, and the Coastal region 13 per cent.[10] The relative importance of the two principal areas, however, has been subject to considerable variation over time. Prior to 1920 for example, the San Joaquin was the principal source of California crude and Los Angeles was relatively unimportant. During the 1920's, the position was reversed, as the great Los Angeles fields were brought into production and the older Valley fields declined. By the end of the 1930's, however, the Los Angeles area had entered upon a secular decline (interrupted by the large Wilmington field discovery in 1937), and with the preponderance of new discoveries being made in the Valley, that area was again increasing in proportionate importance.[11] Information is not available regarding the proportions of the remaining recoverable reserve in the three areas, but it seems probable that somewhat less than half of the undepleted reserve known in 1940 was located in the Los Angeles basin.

The importance of Los Angeles as a refining center is substantially greater. In 1940 it was the site of about 63 per cent of the basic active refinery capacity of the area, whereas the San Francisco Bay area had about 26 per cent and the Valley and coastal areas the bulk of the remainder.[12] In general, therefore, the Los Angeles basin was equipped to refine all of its crude output and tended to be a net importer of crude from other parts of the state. Established pipeline and tanker routes were in operation for the importation of this additional crude oil supply.[13] With so large a crude and refinery output, moreover, the Los Angeles supply exceeded the local needs, and the area was the source of a large proportion of the outshipments to the other four states of the domestic market area and to foreign buyers.

A word may be added about the business organization of the California industry. A large part of all production, refining, transportation, and marketing is done by seven large integrated companies.[14] In the prewar period these companies as a group controlled about 50 per cent of the crude oil production and 80 per cent of the refining capacity and the refined product production and distribution in the Pacific Coast area. The remainder of the crude oil output was produced by about a thousand small and medium sized companies, ordinarily non-integrated producers. The rest of the refinery production originated from 40 or 50 smaller refiners. The independent groups in both production and refining were especially strongly represented in the Los Angeles area, whereas the control of the major companies was proportionately larger in other parts of the

9 See Bain, op. cit., p. 176 for a detailed analysis of prewar exports.
10 Ibid., pp. 32-33.
11 See Petroleum World Annual Review, 1941, pp. 58-62 for a detailed statistical history of production by fields.
12 See U. S. Bureau of Mines, Petroleum Refiners, Cracking Plants, and Natural Gasoline Plants on the Pacific Coast, Jan. 1, 1941.
13 See Bain, op. cit., pp. 77-80 for a brief description of the crude transportation network.
14 Standard, Shell, Union, Tidewater-Associated, Richfield, General Petroleum, and Texas. These are referred to below as the "major" companies. See ibid., p. 28 for a further discussion of their corporate identity.

state. The major companies also controlled almost all of the long-distance transport facilities required to bring crude from other reducing districts into Southern California. The degree of concentration in the control of distributive facilities, on the other hand, was everywhere somewhat smaller.[15]

So much for the general character of the California industry and for the place of the Los Angeles Basin within the industry. What of its economic situation in the period before the war?

The fundamental factor in any long-run appraisal of a petroleum industry is the state of its crude oil reserves. At the end of 1940, the subsurface reserve of recoverable[16] petroleum in California was estimated at 3.52 billion barrels.[17] At the rate of use current in 1940 this amounted to a 15½ year supply, or, anticipating some secular growth in the demand for petroleum products, a 12 to 14 year supply. This figure in itself is not too revealing, however, because a given reserve would have to be produced at a declining rate over a longer period of years, and because some additions to the reserve through discoveries is normally to be expected. The crucial question, therefore, concerned the prospect for more discoveries. Some light is cast on this prospect by a review of recent California discovery history. The adjoining table shows the experience in the four five-year intervals from 1921 to 1940.

TABLE 1

Recoverable Reserves, Discovery and Production of California Crude Oil, 1921-1940

Interval	Recoverable Reserve at Beginning of Interval (millions of barrels)	Discoveries during Interval (millions of barrels)	Production during Interval (millions of barrels)	Recoverable Reserve at end of Interval (millions of barrels)
1921-1925	3,001	1,605	978	3,628
1926-1930	3,628	1,105	1,207	3,526
1931-1935	3,526	410	944	3,012
1936-1940	3,012	1,662	1,151	3,523

Source: Office of Petroleum Coordinatory, Heavy Oil Survey of State of California, Table 1 (calculated)

15 See Bain, op. cit., pp. 28-31 for a further description of the business organization of the industry.

16 Recoverable by currently used primary methods at normal levels of cost. See pp.44 ff below.

17 Heavy Oil Survey, Table 1.

From 1921 to 1940 discovery kept fairly well in pace with production in the California area. The discovery rate, to be sure, was not steady, and there was occasionally a temporary indication of a dangerous dwindling of reserves. This was most marked in the middle 1930's, after a period of restricted exploratory activity. But the latter part of the decade witnessed numerous small discoveries in the San Joaquin Valley and the opening of the large Wilmington pool in the Los Angeles basin, so that by 1940 the known reserve was not below its average level for the preceding two decades. From the surface of the statistics, therefore, the prospect of continued replenishment of the California oil supply seemed good.

A detailed interpretation of the records of discovery and production, however, was somewhat less encouraging. The three major districts of California oil production were discovered and fairly well bounded by the early 1920's. Later discoveries consisted principally of plumbing the full possibilities of these areas--finding additional fields in proved areas and additional depth-zones in known fields. From 1930 onward there was little or no discovery in genuinely new areas. Considering the strictly limited amount of oil presumably available in the Los Angeles basin, the San Joaquin Valley, and the Coastal district, it might have been predicted that further discoveries in these areas would proceed at a rapidly declining rate. In this event, the failure to open new areas over a considerable period lent a discouraging aspect to the long-run prospect of the California oil supply. In spite of such long-run considerations, however, there was no immediate threat of shortage, and the industry itself was more immediately concerned with the problem of current surplus.

The California industry was in fact threatened with a sizeable overproduction throughout the decade from 1930 to 1940. After the large discoveries of 1928 and 1929, the economic potential production rate of California fields (capable of being sustained for a considerable period) was usually somewhat more than double the demand in the domestic market area.[18] After 1929, moreover, the export market was generally unfavorable and incapable of absorbing a large volume of crude oil and refined products at favorable prices.[19] Acute overproduction and a demoralization of price was averted from 1930 onward through a voluntary curtailment and proration program instituted by California producers, in cooperation with the nationwide oil conservation program put into effect by the federal government.[20] The California proration program, under which crude oil producers in the state agreed to accept quotas limiting their output, curtailed production well below what it might otherwise have been, holding it in general at from 50 to 60 per cent of the apparent economic potential. Even so, production substantially exceeded domestic demand in the later 1930's and gave rise to a substantial export surplus. The curtailment program was undoubtedly desirable in that it effected a substantial conservation of the essentially limited oil supply. The necessity for imposing severe curtailment from 1930 onward, however, also reflected the fact that the immediate problem of the California (as of the national) oil industry was one of potential surplus. This was the prevailing situation up to the time of Pearl Harbor.

18 See estimates of the economic potential for California published in Petroleum World in monthly issues from 1928 to 1941. "Economic potential" in this instance refers to a rate of production which can be sustained for some time without damaging the structure of the oil pool, wasting gas pressure, etc. Such a rate is much lower than the maximum rate which could be obtained in "flush" fields for short periods.

19 U. S. Bureau of Mines, California Petroleum Statement, monthly issues from 1929 to 1940.

20 Bain, op. cit., pp. 60-66.

Refinery capacity in California during the 1930's was sufficient in quantity to process almost all of the local crude oil output, exports of crude seldom exceeding 10 per cent of crude production.[21] The output of refineries in the area in the latter part of the decade consisted of about 37 per cent gasoline, 38 per cent heavy fuel oil, 15 per cent Diesel and gas oil, 3 per cent asphalt and road oil, 2 per cent each of lubricants and kerosene, and the remainder miscellaneous products.[22] All of these products were in adequate supply at normally low prices, and the only significant import was a moderate volume of "Pennsylvania" lubricating oil, brought in largely because of a special demand for this grade of lubricant.

The domestic demand for gasoline was of course preponderantly automotive in character. Residual fuel oil, on the other hand, was the principal industrial fuel of the area. Annual domestic consumption of fuel oil in the five western states was about 80 million barrels annually, consumed 33.3 per cent by railroads, 21.1 per cent by vessels, 12.5 per cent in mining and manufacture, and 10.9 per cent by federal government agencies.[23] Diesel and gas oil, the third important product, was used primarily by vessels, for heating purposes, and by highway trucks.[24] The domestic market for refined products was centered principally in California, which consumed 71 per cent of the domestically used gasoline, 73 per cent of residual fuel oil, and 68 per cent of Diesel and gas oil.[25] Washington, Oregon, Arizona, and Nevada followed in that order of importance.

The state of technique in the industry was roughly on a par with that in the rest of the industry in the United States. Basic distillation capacity was relatively modern and of good design. The industry was adequately supplied (in terms of the existing market demand) with thermal cracking facilities suitable for increasing the supply of automotive grade gasoline. Although it had a small amount of polymerization and alkylation capacity for the production of higher octane motor fuels, however, it was not equipped to produce a large amount of gasoline of aviation grade or substantially to increase the octane rating of ordinary automotive gasoline. This was a natural result of the fact that until 1941 the total demand for aviation gasoline had been very small.

In summary, then, the situation in the California industry in 1940 was one of satisfactory adjustment of supply to the conditions of peacetime demand. Crude oil reserves were for the time being adequate, and the rate of their exploitation had been successfully curtailed in accordance with the needs of the market. Refinery capacity and output were adjusted to market needs, and in general the industry was in a condition of relative stability. In what way has the war situation altered this picture?

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21 U. S. Bureau of Mines, California Petroleum Statements, 1929-1940.

22 U. S. Bureau of Mines, California Petroleum Statements, 1929-1940, (calculated).

23 U. S. Bureau of Mines, Survey of Fuel Oil Distribution in the Pacific Coast Territory, 1940.

24 Petroleum World Annual Review, 1941, p. 324.

25 Bain, op. cit., pp. 142, 163, 167.

CHAPTER III

THE EFFECT OF THE WAR PERIOD ON THE INDUSTRY

The war-period history of the California petroleum industry has been in many respects complicated, and numerous of its details understandable only by the technical expert. Nevertheless, the broad outlines of the war experience may be summarized for general purposes under six main heads.

First, there has been a rapid and continuing expansion in the total demand for refined products in the Pacific Coast area. This has resulted in part from the general expansion of industrial and transportation activity in the Far West, and in part from increased military demands for gasoline and other products.

Second, there has been a consequent increase both in the rate of crude oil production and in the rate of developmental and exploratory activity in California. This has in turn led to some alteration in previously held views of the crude reserve situation, both for the state as a whole and for the Los Angeles basin in particular.

Third, there has been a rapid expansion of refinery plant along new technical lines. The primary development has been in new types of plant for the production of aviation gasoline; of lesser importance from the point of view of the industry are new plants for producing synthetic rubber components and explosives.

Fourth, there has been an essentially temporary but very marked change in the composition of the demand for refined products. The normal export markets have been almost entirely cut off. Within the domestic market, the civilian gasoline demand has been artificially curtailed by the tire and automobile shortage and by gasoline rationing, whereas the military demand for gasoline has risen very greatly and currently dominates the gasoline market. The demand for heavy fuel oil, moreover, has risen more rapidly than that for other products, thus upsetting the normal ratio of the various refined yields.

Fifth, there has been a steady depletion of above-ground stocks of both crude oil and refined products, so that these inventories are currently abnormally low.

Finally, there has been some disruption of the normal competitive relationships in the market, as a result of changes in civilian demand, war-time cooperative schemes among refiners, and other war changes.

The combination of these effects has wrought considerable changes in the industry. Let us consider them in turn.

THE RISE IN DEMAND

Modern war requires that the economies of belligerant countries operate under forced draft. Not only must the output of direct munitions industries be tremendously increased, but also that of the industries supplying basic raw materials. Even with a foreknowledge of this general truth, however, it would have been difficult to anticipate the unprecedented expansion which war has forced on the California petroleum industry. The reasons for this exaggerated growth are two-fold. First, the rate of industrial activity on the West Coast was greatly expanded, especially in aircraft and marine ship production but also in many other lines. Second, the proximity of the West Coast to the Pacific theatre of war has resulted in a great addition to the land and ocean transportation activity in the area, thereby increasing demands for all petroleum fuels, and has also thrown on the California oil industry the primary responsibility of supplying gasoline and other petroleum products to an important portion of the armed forces at home and overseas.

The magnitude of the increase in the total demand [1] for petroleum products in the Pacific Coast area is indicated in Table 2. If we take the prosperous year 1941 as a base period, it is evident that by January of 1943 (about a year after Pearl Harbor) demand had risen less than 7 per cent, but that in July of 1943 it was up 31 per cent, in January of 1944 up 42 per cent, and by March of 1944 up 45 per cent from the 1941 average. Thus it appeared that before 1944 was out, the California industry would probably have experienced an expansion of demand of at least 50 per cent above the highest recent peacetime year. This expansion in demand put a severe draft on the productive capacity of the California industry. Although it could be supported temporarily in part by a depletion of the large prewar stocks of crude, it made absolutely necessary a substantial increase in the rate of output of crude oil. We therefore turn now to the crude production picture.

TABLE 2

Total Demand for All Petroleum Products (in Barrels per Day) in the Pacific Coast Territory from 1940 to March, 1944

Time interval	Total daily demand (000 bbls.)	Time interval	Total daily demand (000 bbls.)
Year 1940	676	Jan. 1943	748
Year 1941	700	July 1943	918
Year 1942	670	Jan. 1944	995
July 1942	790	March 1944	1018

Source: Bureau of Mines, California Petroleum Statements, Jan. 1940 - Mar. 1944.

1 "Total demand" represents the aggregate of the physical volume (in 42 gallon barrels) of all petroleum products sold or delivered to users thereof, plus losses of these products in the course of storage or processing.

CRUDE OIL PRODUCTION, DEVELOPMENT, AND DISCOVERY

The California producing industry has succeeded very well in increasing its output of crude oil sufficiently to meet almost all of the increase in demand just described. To be sure, the increase in the production of crude has consistently lagged behind the rise in the current consumption of crude and its products, with the result that there has been a steady draft on stocks of crude and refined products. (These declined from 151 million barrels at the end of 1940 to 85 million barrels on May 31, 1944, an aggregate decrease in 3 1/3 years equal to about a quarter of 1943 crude output.)[2] But this stock decline has not been rapid, and the industry is currently meeting demands for crude without assistance from rationing other than that of civilian gasoline. The increase in crude oil production since 1940 is shown in Table 3.

Crude oil production was increased 32 per cent from the average of 1941 to May of 1944, and was still rising steadily at the latter date. The supply of crude thus made available, together with natural gasoline production (not shown in the table) and withdrawals from stock, offset the indicated demand. This surface indication of California's ability to expand production, however, is not in itself very revealing. To ascertain how the crude supply situation has actually developed, we must determine the manner in which the recorded increase of output was effected.

The principal avenues for the expansion of crude oil output as of the beginning of the war period were: 1) the opening of shut-in wells, 2) the relaxation of curtailment on producing wells, 3) the drilling of new wells in established fields, and 4) exploratory drilling for new oil reserves. Let us examine the experience with each of these alternatives in turn.

As the demand for crude oil increased, a first avenue for the extension of output was the opening of shut-in wells.

TABLE 3

Total Crude Production (in Average Barrels per Day) in California from 1940 to May, 1944

Time interval	Daily production (000 bbls.)	Time interval	Daily Production (000 bbls.)
Year 1940	612	Jan. 1943	764
Year 1941	631	July 1943	776
Jan. 1942	629	Jan. 1944	813
July 1942	687	May 1944	835

Source: Bureau of Mines, California Petroleum Statements, 1940-1944, and American Petroleum Institute, Summary of California Oilfield Operations, May, 1944.

2 See pp. 26 to 27 below.

At the end of 1940, in line with the curtailment policy then in effect, about 25 per cent of all the potentially productive wells in the state of California were fully shut in--i.e., capped and not producing.[3] The potential production of these wells was considerable, and represented a quickly available reserve capacity for the producing industry. In order to increase current output, shut-in wells were opened progressively from 1940 onward, until in April of 1944 the number of shut-in wells was only one-fifth what it had been in December of 1940.[4] The decline in the number of shut-in wells is shown in Table 4.

It will be noted that from December 1940 to December 1942, about half of the shut-in wells were brought into production; that during 1943 the shut-in situation was relatively unchanged; and that in 1944 about 60 per cent of the remaining shut-in wells were opened. The accompanying history was somewhat as follows. From the beginning of the expansion of total demand until well along in 1943, the increase in refined product demand was concentrated largely in heavy fuel oils and was much slighter in the lighter refined products. As a consequence there was an especially large demand for heavy crudes, which yielded high proportions of fuel oil, and less increase in demand for light crudes. From 1940 until late in 1943, therefore, practically all wells in fields producing heavy crude were opened, but shut-in wells producing light crude were held in reserve. Then, with the continued rise in total demand and with the rapid increase in gasoline demand which occurred in 1943, the remaining reserve of shut-in wells was tapped and production was correspondingly augmented.

TABLE 4

Number of Shut-in Oil Wells
in California, December 31, 1940 to April 30, 1944

Date	Number of shut-in wells	Date	Number of shut-in wells
Dec. 31, 1940	4828	Dec. 31, 1943	2420
Dec. 31, 1941	3916	Apr. 30, 1944	966
Dec. 31, 1942	2479		

Source: Data supplied by Conservation Committee of California Oil Producers.

3 Petroleum World Annual Review, 1941, pp. 81-114b (calculated).

4 From data supplied by the Conservation Committee of California Oil Producers, Los Angeles.

By the middle of 1944, therefore, over 80 per cent of the number of "reserve" wells (and presumably over 80 per cent of their total capacity) had been brought into production, and California's single most important emergency reserve was being drawn upon.

At the same time that wells were being shifted from the "shut-in" to the "producing" category, the degree of curtailment of all producing wells was being successively lessened. In 1940 and 1941 the estimated sustainable production potential (within the limits of economical operating practice) of all California wells, including shut-in wells, was from 950,000 to 1,050,000 barrels per day, whereas actual production was only 612,000 barrels per day in 1940 and 631,000 in 1941.[5] (This curtailment was accomplished by agreement through the proration authority.)[6] Actual production was thus about 60 per cent of practical capacity. With the expansion of demand, curtailment quotas were enlarged and production crept closer and closer to capacity. The relation of the potential of producing (excluding shut-in) wells to production was as follows during the last three years:[7]

Year	Potential in barrels per day of Producing wells (000 bbls.)	Production in barrels per day of Producing wells (000 bbls.)
1942	875	677
1943	839	777
1944	864[8]	821[9]

The sustainable potential of producing wells is of course subject to several concurrent influences: 1) the addition of new wells by drilling, 2) the opening of shut-in wells, and 3) the dwindling of the potential of existing wells. In spite of considerable gross additions to the potential from the first two sources, the preceding figures reveal that the net potential was tending to decline as more and more oil was drawn from the limited reserve.[10] By mid-1944, there were few shut-in wells left and the maintenance or further extension of the potential of producing wells had to originate almost entirely from new drilling.[11]

The third source of increased production was new oil wells, drilled either in established or in newly discovered fields. The degree of success accompanying new drilling efforts, particularly exploratory or "wildcat" drilling, is the strategic element in the long-run supply situation. Unfortunately, exploratory efforts in California since 1938 have reaped an insignificant reward, and the total supply situation is consequently discouraging. Drilling, including wildcatting, was at a normal level in 1940 and 1941, but no important discoveries were made. In 1942, further drilling of existing reserves was severely retarded

5 Estimates of sustainable production potential from monthly issues of Petroleum World, 1940 and 1941. Crude production from U. S. Bureau of Mines, California Petroleum Statement, 1940-1941.

6 See Bain, op. cit., pp. 60-66.

7 From data supplied by the Conservation Committee.

8 Potential on April 30, 1944.

9 Average production for first four months of 1944.

10 That is, the potential dropped from 1942 to 1943 in spite of some additions, was temporarily replenished by additions in 1944.

11 It may be noted that the policy with respect to increasing curtailment quotas paralleled that followed in releasing shut-in wells. That is, heavy crude wells were exempted from proration first, and lighter crude wells later, largely after mid-1943, in response to increasing demands for gasoline.

by WPB, OPC, and PAW priority orders affecting drilling and producing equipment.[12] These orders limited drilling through well-spacing regulations which presumably accorded with scientific conservation practice, but which did not accord with previous California industry practice in this regard. These regulations were progressively relaxed as the demand for oil increased and after California producers effectively contended that the original well-spacing regulations were ill-fitted to the geological and physical characteristics of California fields. Thus there was a revival of drilling activity in 1943, and a further acceleration of drilling effort during 1944. The relationship of current to past drilling activity is indicated in Table 5.

Drilling has thus been proceeding since 1942 at a normal or super-normal rate. Most of this drilling is concentrated in the exploitation of old fields or in the drilling of new fields subsequent to their discovery. As such it could contribute substantially to sustaining the potential and actual production of the California area.

TABLE 5

Number of Producing Wells
Completed in California from 1935 to 1944

Year	Number of wells completed	Year	Number of wells completed
1935	763	1940	890
1936	802	1941	941
1937	1164	1942	569
1938	1000	1943	1163
1939	865	1944 [13]	1647

Source: Data supplied by Conservation Committee, and Petroleum World Annual Review, 1941, pp. 66-67.

Yet so far as drilling has been undertaken in newly discovered fields, it has added a disappointingly small amount to the current output. Wildcat, or initial exploratory wells, have been drilled in at least normal numbers during the last several years (as shown in Table 6) and they have resulted in the discovery since the end of 1940 of 24 new fields producing oil. Where oil has been discovered, the wildcat wells have been followed by additional drilling, which makes up a part of the total drilling shown in Table 5. But the total result of all wildcatting since 1940 has been an unsubstantial addition to known oil reserves, and the result of all drilling of newly discovered fields has been only a small increase in current production.

Between December 31, 1940 and December 31, 1943, the known recoverable reserve in California declined from 3,523 million to 3,337 million barrels, a net decrease of 186 million barrels.[14] Since the aggregate production of the

12 So for example Petroleum World, Jan 1942, pp 18 ff.; Sept. 1942 pp. 31 ff.; Oct. 1942, pp. 14 ff.; Mar., 1943, pp. 20 ff.; Apr. 1943, pp. 18 ff.

13 Estimate based on the first four months of the year

14 Estimate for 1940 from Heavy Oil Survey, Table 1. Estimate for 1943 from "40 Years of the Oil Age", American Petroleum Institute Quarterly, April 1944.

three intervening years was 760 million barrels, the gross addition to the reserve was evidently about 574 million barrels. The bulk of this addition, however, represented merely revisions of previous estimates of the size of reserves discovered before 1941,[15] and the gross addition through new discoveries in three years was less than 100 million barrels, or 35 per cent of the production of 1943. The 14 new fields discovered in 1943, for example, added a total reserve equal to only 22 per cent of the production of that year.[16] Nearly all of the discoveries made since 1940, in fact, are of a secondary sort, resulting from combing over the unexplored possibilities in the vicinity of known producing fields in order to pick up odd "pockets" of oil. There has been no success in opening large new areas (as in Los Angeles in the early 1920's), in discovering large new depth zones (as in Los Angeles and elsewhere after 1928), or in opening a first-rate field in known areas (as in Wilmington in 1937). In almost every aspect, the discovery record has been discouraging.

TABLE 6

Number of Wildcat Wells Drilled,
and
Result of Drilling, in California from 1938 to 1943

Year	Number of wells drilled	Oil wells	Gas wells	Dry holes
1938	135	10	1	124
1939	102	4	0	98
1940	104	6	2	96
1941	124	13	3	108
1942	163	18	1	144
1943	186	14	7	165

Source: Petroleum World, October, 1943 and May, 1944.

It is therefore not surprising that the rather extensive drilling which has exploited the newly discovered fields is yielding only a small addition to the current oil supply. In May of 1944 the 24 fields discovered since the end of 1940 supplied only 5 per cent of the production of the state.[17] The California industry was living almost entirely on reserves discovered before 1940.

The effect of the war period on the crude reserve and production situation to date is therefore briefly as follows. The current production, greatly increased, has far exceeded the rate of new discoveries, in spite of a healthy rate of exploratory activity. As a result, the remaining known reserve is declining at a rapid pace. The current productive potential has declined about 15 per cent from its 1940 level and a further decline may be anticipated. The industry is now exploiting almost all of its productive capacity. Because the potential of existing wells will decline gradually, however, and because additions can be

15 Heavy Oil Survey, Table 1.

16 Petroleum World, May, 1944, p. 54.

17 American Petroleum Institute, Summary of California Oil-field Operations, May, 1944.

made through further drilling of known reserves and possibly through discoveries, the industry should be able to get through the war period at approximately the current rate of production. At the end of the war it will probably have a substantially smaller recoverable reserve and a smaller current potential production than it had in 1940. What this implies for the postwar situation must be examined at a later point.

The preceding analysis is concerned with the crude oil situation for the state of California as a whole. It is now pertinent to inquire regarding the degree to which the Los Angeles basin has shared in the overall changes described. In general, the war period has found the Los Angeles area becoming relatively less and less important as a source of crude oil. The southern district has been able to expand the production of its existing wells and fields by much less than the other districts, and exploratory effort within its limits has been almost wholly unrewarded. The Los Angeles basis is thus rapidly becoming an old and fully exploited oil producing area, the production of which will presumably be subject to gradual decline hereafter.

The decline of the area as a source of the California oil supply is shown in the following figures:[18]

Year	Production of state of California (barrels daily)	Production of Los Angeles Basin (barrels daily)	Los Angeles percentage of total production
1940	608,700	294,525	48.5
1941	627,645	286,544	45.7
1942	677,073	299,583	44.2
1943	777,157	304,558	39.2
1944 [19]	821,069	313,841	38.2

Not only has the share of California oil supplied by Los Angeles declined considerably, but the absolute production of the area has increased only slightly even under the severe pressure of wartime demand. From 1940 to 1944 the production of the Los Angeles basin increased by only 6.3 per cent, while the rest of the state rose by 61.5 per cent, or ten times the increase of Los Angeles. Only the untapped potential of the more northerly fields of California enabled the oil industry of the state to cope successfully with the wartime emergency.

The failure of Los Angeles production to increase substantially is primarily a reflection of the fact that before the war the ratio of its potential to its actual production was lower than that for the rest of the state. That is, the bulk of the shut-in or curtailed potential production in 1940 was found in the San Joaquin and Coastal area, whereas in the Los Angeles basin actual production was much closer to full capacity.[20] At any rate in 1942, the first year in which practical potentials for separate districts were published, the Los Angeles potential was only 108 per cent of actual production, whereas for the remainder of the state the potential was 146 per cent of production.[21] It is thus apparent that as of the beginning of the war Los Angeles did not have the

18 From data supplied by the Conservation Committee

19 First five months.

20 A situation to be expected in an area where most fields are well past their peaks.

21 From data supplied by the Conservation Committee.

unexploited reserve capacity of the rest of the state, and that the share of the state production it then supplied exaggerated its long-run place in the producing industry.

The decline of Los Angeles as a source of crude supply is also attributable to the failure of exploratory efforts to uncover new crude supplies in the area during the war period. Of the 24 new fields discovered in California in 1941, 1942, and 1943, only three were found in the Los Angeles basin. and these are apparently of minute importance, accounting in May 1944 for only 2.4 per cent of the current production from all new fields, or one-tenth of one per cent of the production of the state.[22] The lack of new discovery in the Los Angeles area, together with the fact that most existing fields were already rather thoroughly drilled, presumably explains the fact that only about one-fifty of total drilling activity in the past three years has been situated in Los Angeles.

In summary, the experience of the war period seems to indicate that the Los Angeles basin, as the most fully exploited and heavily produced crude oil distract in California, is past its productive peak and will be the first of the three main districts to decline. Although the northern producing districts seem to have at least a few remaining potentialities untapped, the Los Angeles area seems to have reached its limit and to be ready to enter into a period of slowly but steadily shrinking-production. If this is to be the case, and if Los Angeles retains its refinery capacity, it will become increasingly a crude-importing area.

WARTIME DEVELOPMENT OF REFINERY PLANT

The wartime changes in refinery capacity in California have not been as large as those in crude oil production, but their size and character are nevertheless significant. The refinery plant developments have been of two main types. First, there has been some net addition to the basic capacity for distillation, through which nearly all crude oil passes in the initial process of refining, and some replacement of old distillation capacity abandoned since 1940. The net addition could be small because of the substantial excess capacity in existence in 1940. Second and more important, there has been a very substantial addition to cracking plants and other plants devoted to the production of high-octane gasolines, all of modern types not generally in use in the industry before the war. These additions have effected a marked change in industry refining technique and may have a considerable impact on the postwar market situation. An additional change of less importance to the petroleum industry has been the building of some synthetic rubber capacity on the Pacific Coast.

At the end of 1940 the basic distillation capacity of the California refinery industry was as follows:[23]

	Barrels per day of crude oil input
Operating plant	771,110
Shut-down plant	183,150
Total	954,260

22 American Petroleum Institute, Summary of California Oilfield Operations, May, 1944.

23 U. S. Bureau of Mines, Petroleum Refiners, Cracking Plants, and Natural Gasoline Plants on the Pacific Coast, Jan. 1, 1941.

It will be noted that operating as well as total capacity was substantially in excess of the rate of crude oil production in California, which averaged 608,700 barrels per day in 1940. The capacity of California cracking plants at the same time was as follows:[24]

	Barrels per day of gasoline output
Operating plant	98,205
Shut-down plant	24,100
Total	122,305

The input capacity of these cracking facilities was approximately treble their indicated gasoline output; considering this, there was enough cracking capacity to process the bulk of the charging stock made available from current distillation operations.

The increase of distillation capacity from the end of 1940 to the beginning of 1944 is shown by available statistics as follows:[25]

	1944 capacity in barrels per day of crude input	Change over 1940 in barrels per day of crude input
Operating plant	869,000	+97,890
Shut-down plant	101,650	-81,500
Total	970,650	+16,390

The principal apparent change in distillation capacity has thus been a large net shift of reserve plant from idle to active status; at the same time there has been a smaller net addition of new plant, equal to about 1.7 per cent of the total prewar capacity. Operating capacity has been expanded sufficiently to process the large wartime crude output (which in 1944 was approaching 850,000 barrels daily), but there is a much smaller margin of excess capacity than existed in 1940.

The gross change in refinery capacity, however, has apparently been greater than is indicated by these data. From the end of 1940 to the beginning of 1944, thirteen small refiners with an aggregate capacity of 27,000 barrels daily went out of business and vanished from the roster of refinery capacity. Most of their plants were old or obsolete and were presumably scrapped or left idle; and there has thus been a sufficient additional construction of new distillation units to replace this capacity. Further, operating refiners have been undertaking a moderate amount of retirement and replacement of old capacity. The resulting gross additions for replacement and expansion of distillation plant appear to have amounted to 80,000 barrels of daily capacity—almost 10 per cent of total prewar plant. At least three-fourths of these additions appear to have been made by the seven major refiners. This construction, taken together with the elimination of several small

24 Ibid.

25 Oil and Gas Journal, April 13, 1944, Sec. 2, pp. B-107-B-111. (The Bureau of Mines is not currently releasing data on refinery capacity on the Pacific Coast.)

refiners and the net movement to inactive status of several more, has resulted in an increased concentration of effective distillation capacity in the hands of the few major companies.[26] For the industry as a whole, the overall effect has been a slight increase in the quantity and a more marked increase in the quality of distillation capacity.

More spectacular developments have been made in cracking and other higher process plants. The available statistics show the following change in cracking capacity from 1940 to 1944:[27]

	1944 capacity in barrels per day of Gasoline output	Change over 1940 in barrels per day of Gasoline output
Operating plant	136,930	+38,725
Idle plant	1,900	-22,200
Total	138,830	+16,525

These statistics, showing a net addition to cracking output of only 16,525 barrels of gasoline output daily, are apparently deficient as an indication of the current situation; other sources indicate a net addition by the Fall of 1944 of about 50,000 barrels daily of gasoline output, or 150,000 barrels of input of charging stock.[28] This would constitute an extremely important net addition to the refinery plant of the California industry (about two-fifths of prewar capacity) and alone would change the technical aspect of the postwar industry. Mere indications of the quantitative change in capacity, however, are in this instance not very revealing. The new construction here has not been in older types of plant but has represented substantial innovations in cracking technique as well as the addition of new types of capacity not yet shown in assembled statistics. Nearly all of the new facilities have been designed with an eye to enhancing the output of high-octane or aviation gasoline.

The largest scale addition to higher process plant has been that of catalytic cracking capacity. Such plant represents an evolution of the older type thermal cracking units which were the principal prewar type. Catalytic cracking facilities are used to "crack" light fuel oils (obtained from distillation) in order to produce a high-octane gasoline base stock. The stock obtained is 80-octane or higher (the approximate rating of prewar premium automotive fuel) as compared with a 70-octane gasoline yielded from thermal cracking facilities. The stock may be reformed to increase the octane number further. Catalytic cracking is the volume process in aviation gasoline manufacture, supplying about 70 per cent of the required stock.[29] There was little if any catalytic capacity in the Pacific Coast before the war. Since 1940, ten such plants have been constructed (eight in the Los Angeles area)[30] with an aggregate capacity of 154,350 barrels daily of input, of which 85 per cent is situated in Los Angeles.[31] The maximum output of these plants should be in the neighborhood of 650 million gallons per year of very high octane gasoline, a

26 Oil and Gas Journal, April 13, 1944, Sec. 2, pp. B-107-B-111.

27 Ibid.

28 W. G. Moore and T. G. Elder, "Effect of Catalytic Cracking on the Postwar Supply of Motor Gasolines and Fuel Oils," National Petroleum News, June 7, 1944, pp. R-334 ff.

29 Oil and Gas Journal, April 13, 1944, pp. 158 ff.

30 Ibid.

31 Moore and Elder, op. cit.,

quantity certainly sufficient to influence the west coast market.

Second in quantitative importance in new-type facilities are alkylation plants. The alkylation process is employed to "condense" lighter gaseous molecules (iso-butane and butene) to form commercial iso-octane gasoline of an octane rating of from 90 to 95.[32] This alkylate fuel constitutes the high-potency blending agent in aviation gasoline manufacture. It generally comprises about 30 per cent of finished aviation fuel, but the potential gross output from the process is limited by the relative shortage of field and refinery gases which it uses as a raw material.[33] By 1944 there were 7 alkylation plants in Los Angeles and 7 elsewhere in California, all built during the war period,[34] but their capacity is not known.

A third type of plant, auxiliary to the alkylation process, is found in isomerization capacity, which produces iso-butane for alkylation. There are 5 new plants of this type in Los Angeles and 4 elsewhere in California.[35] Finally, there have been several new gasoline plants of miscellaneous type (including one hydrogenation plant) constructed in California since 1940.

The total investment of the California industry in these facilities since Pearl Harbor (large private finance) has been about 160 million dollars,[36] as opposed to a 9 million dollar investment undertaken before December of 1941. Their construction has greatly affected both the present wartime and future peace-time potential of the industry. Currently, they enable Pacific Coast refineries successfully to meet a very large military demand for aviation and other high-octane motor fuels. In the succeeding peacetime period they will certainly enable the companies owning them--the seven major companies and two large independent refiners--greatly to increase the quality of automotive fuel. At the same time they replace a good deal of obsolete skimming plant abandoned during the war period, and considerably advance the obsolescence of much skimming plant and older type cracking plant still in use. When the present high rates of output are no longer required and excess capacity emerges, the effect of this new capacity on the competitive situation in the industry may be substantial.

A peripheral wartime development in refinery capacity has been that of synthetic rubber capacity. Approximately enough such capacity (all based on petroleum products) has been built on the Pacific Coast to make this area self-sufficient in the synthetic product. Butadiene plants with an annual capacity of 57,000 tons and styrene plants with a capacity of 25,000 tons per year have been built in Los Angeles. These supply the basic constituents of the rubber. In addition copolymer units for synthesizing the components have been erected by rubber-tire companies and have a capacity of 60,000 tons. This represents about 12 per cent of the national capacity.[37] Should synthetic rubber production be maintained, there will thus be a significant addition to the Southern California industrial structure. The resulting total drain on petroleum output, however, is not very large, and is of significance now principally because synthetic rubber plants compete with aviation gasoline capacity for scarce gaseous products of the butane type.

WARTIME CHANGES IN THE COMPOSITION OF DEMAND

We have already referred to the large aggregate and percentage increase in the total demand for refined products which the California industry has experienced

32 See Bain, op. cit., pp. 94-95 for a further discussion of alkylation and polymerization.

33 Oil and Gas Journal, April 13, 1944, pp. 158 ff.

34 Oil and Gas Journal, April 13, 1944, pp. 158 ff.

35 Ibid.

36 Petroleum World, Jan. 1944, pp. 36 ff.

37 Petroleum World, September 1943, pp. 28-31.

because of the war. The demand in May of 1944 was 223,000 barrels per day, or 36 per cent above the average demand in 1940.[38] Equally as important as this overall change, however, are the changes in the composition of the total demand. Two such changes stand out. First, there has been a marked shift in the proportions in which the several refined products are demanded and produced--in effect, the demand for some products has increased much more rapidly during the war than that for others. Second, the character of the buying market for some refined products has been altered, with the export markets being curtailed, civilian markets shrinking or failing to increase, and the military demand rising to a position of great importance.

The general character of the change in the relative proportions of various refined products demanded is reflected in the data on refinery output shown in Table 7. This table indicates the percentage which the output of each of the six principal refined products represented of the total of such outputs from 1940 through 1943. Heavy fuel oil output increased steadily as a proportion of total output from 1940 onward, whereas the proportion of gasoline to total output declined markedly after 1941. Diesel fuel output also experienced a perceptible net decline. Changes in the other products were of little importance, with the exception of a temporary increase in asphalt and road oil requirements in 1942 concurrent with the development of many military bases on the west coast. The principal shift is from the lighter and higher-valued products--especially gasoline--to the heavier and cheaper residual fuel oil output. The increase in the output of this product from 1940 to 1943 was about 57 per cent, whereas Diesel and gas oil output rose only 35 per cent, and gasoline output less than 19 per cent. The percentage change in fuel oil demand, moreover, actually exceeded that in its output, with a resulting large draft on prewar stocks.[39]

TABLE 7

Percentage Distribution among Six Products of Total Physical Output of These Products in California Refineries, 1940-1943

Product	Composition of Total Output (per cent)			
	1940	1941	1942	1943
Gasoline	37.0	38.0	34.8	32.5
Fuel Oil	41.1	41.4	45.4	47.6
Diesel and gas oil	15.0	14.0	12.7	13.8
Asphalt and road oil	3.2	3.6	4.8	3.2
Kerosene	1.8	1.2	1.1	1.6
Lubricants	1.9	1.8	1.2	1.3
Total	100.0	100.0	100.0	100.0

Source: U. S. Bureau of Mines, California Petroleum Statements, 1940-1943 (calculated).

38 See Above, p. 11.

39 See below, pp. 26-27.

The principal sources of this disproportionately great increase in the requirement for fuel oil were first the great acceleration of industrial activity in munitions industries (shipbuilding and aircraft) on the west coast, with a resulting increase in rail traffic and in power and raw material production, and second a further addition to rail traffic from military activity located in or based on the Pacific Coast. The war also of course resulted in an increased demand for gasoline. But whereas fuel oil is a basic industrial fuel used immediately in expanding production for war, gasoline is a fuel used in completed military equipment, and the increase in the military demand for it necessarily lags the increase in the demand for fuel oil. Hence the early great rise in the demand for fuel oil, which is in part being overtaken by the demand for gasoline as the year 1944 progresses.

At the current writing, nevertheless, the total demand for refined products is abnormally weighted in the direction of fuel oil. The fuel oil demand, moreover, is much larger than would be created by normally prosperous peacetime economic activity in the area, being artificially expanded by military rail traffic and munitions industry activity. Under the most favorable circumstances, therefore, a substantial postwar cut in fuel oil output may be anticipated, and a corresponding readjustment of the inter-product relationship of refinery production.

In the case of gasoline demand, the wartime change has been more complicated. Whereas the expansion of fuel oil requirements has been effected through increases in demand by the usual categories of civilian buyers, the character of the gasoline buying market has been substantially changed. As with all refined products, of course, the export market, which before the war took 17 per cent of the gasoline output, has been cut off. Further than this, however, there has been first an artificial restriction of civilian gasoline demand, through rationing, and second a very large increase in direct military purchases of gasoline.

In normal times about three-quarters of domestic gasoline sales in the western area are made to users of individual passenger cars, and about one-quarter to commercial vehicle operators. The total civilian demand for gasoline has been apparently rather insensitive to changes in gasoline price, only moderately sensitive to these in the level of income, and primarily responsive to changes in the number of motor vehicles in use. During the war period, total consumer and business income on the Pacific Coast has increased very greatly, whereas gasoline prices have been relatively stable.[40] Surprisingly enough also, automotive vehicle registrations have declined very little since 1941. In 1943 they were only about 6 per cent below 1941 and still above 1940 for the five-state area. (See Table 8) The immigration of automobile-owning population has thus so far largely counteracted the natural decline due to scrapping and abandonment of the total stock of motor vehicles in the west.

The civilian buying potential for gasoline has thus not decreased during the war, and has probably risen. At the same time, the natural demand has been artificially curtailed since Pearl Harbor, first by the tire shortage and by voluntary self-rationing, and later by compulsory rationing through the Office of Price Administration. The net effect of these various influences on the realized civilian demand for gasoline is shown in the following data on total tax-paid (civilian) gasoline sales in the five western states from 1940 to 1943:[41]

40 During 1941 an average upward adjustment of one cent per gallon was made in major-company posted prices, and was finally approved by OPA. Since then, the only important adjustments have been increases in minor-company prices up to the level of major prices, wiping out the customary major-minor differential. A uniform price ceiling for all refiners at the 1941 level for the majors was recently approved by OPA.

41 Petroleum World Annual Review, 1941, pp. 334-347; 1942, pp. 333-348; 1943, pp. 306-319. Also Service Station News, April, 1944, p. 24.

Year	Annual tax-paid sales (millions of gallons)	Relative to 1941 sales
1940	2,672	89
1941	3,011	100
1942	2,704	90
1943	2,318	77

TABLE 8

Motor Vehicle Registrations
in the Five Pacific Coast States, 1940-1943

State	1940	1941	1942	1943
Total	3,951,645	4,252,774	4,110,230	3,999.075
California	2,803,276	2,996,552	2,873,100	2,790,576
Washington	565,360	626,711	620,751	605,898
Oregon	397,980	434,089	422,593	413,341
Arizona	140,951	147,262	143,380	138,862
Nevada	44,078	48,160	50,406	50,398

Source: Service Station News, April, 1944, p. 24

The tire shortage and voluntary rationing in effect from January to December of 1942 was sufficient to bring the civilian use of gasoline back to about the 1940 level, or 10 per cent below 1941. Compulsory rationing, in effect throughout 1943, cut civilian demand to a level 23 per cent below that of 1941, or 13 per cent below 1940.

The movement of civilian demand from month to month through this period and into the early part of 1944 shows progressive easing of the official curtailment on civilian gasoline consumption after the initial cut in December of 1942, a tendency that was not greatly checked by two successive reductions in the weekly "A" ration for unlimited driving. Especially surprising, moreover, is the fact that the overall curtailment accomplished by an apparently stringent rationing policy has been so small a proportion of the prewar demand.

The small degree of net curtailment accomplished seems attributable first to the increased volume of truck and bus travel in the area, which has not been perceptibly affected by rationing, and second to the rather liberal issuance of supplementary rations to individuals and businesses for occupational driving.[42] Although current information on the proportion of gasoline used by commercial vehicles is not available, present data reveal that of all passenger automobiles

42 There has apparently been a rather liberal policy in the issuance of "C" cards for occupational and to-work-and-back transportation, and in the size of the rations granted to "C" card holders. Thus "B" and "C" card holders, representing only about 46 per cent of drivers, used about 75 per cent of all passenger car gasoline even when the "A" ration was 4 gallons per week. Yet when gasoline shortages impended, the "A" ration bore the brunt of the cut.

in the five-state area in 1943, about 54 per cent had "A" rations only, 25 per cent "B" rations, and 21 per cent "C" rations. Whereas the basic "A" ration then in effect was 192 gallons of gasoline per year, the average use for all cars is estimated by one source as 580 gallons per year in California, 556 gallons in Oregon, and 533 gallons in Washington.[43] Office of Price Administration figures, on the other hand, showed an average ration of 407 gallons per car for the five western states.[44] Neglecting the effect of black market gasoline sales, which do not influence the latter figure, it would appear that at the minimum the average gasoline use per car for the total of the "B" and "C" card groups was about 660 gallons per year, or the equivalent (at the official ratio) of about 10,000 miles per year of driving. With 46 per cent of all passenger cars able to average approximately a normal peacetime mileage with official rations, with commercial vehicle travel increased, and with a certain amount of gasoline being acquired by extra-official means, it is not surprising that total civilian consumption was cut so little.

As civilian demand has been kept from rising and been somewhat curtailed, the military demand for gasoline has risen steadily. The total gasoline purchases of the federal government in California in 1941 were less than 5 per cent of total domestic demand. By March of 1942 they were 17.5 per cent of the total, and by March of 1943, 39.2 per cent of the total, although their average level during 1942 was low enough that California was temporarily faced with a gasoline surplus.[45] The increase of military demand was extremely rapid during 1943, the federal government exceeding the civilian demand for the first time in September of that year. Since then the increase in military purchases has proceeded at a more moderate rate, and amounted to 57.3 per cent of total demand in March of 1944. In that month, the federal government purchases were about 30 times those in March of 1941. It should be noted that a large proportion of the total military gasoline requirements are for aviation or other high-octane gasoline, and have taken practically all of the output from the new refinery facilities described in preceding pages.

The increase in federal government purchases has of course far outweighed the reduction of civilian purchases, with the result that the aggregate domestic demand for gasoline has risen greatly. The California domestic demand in the month of March in the years from 1941 to 1944 was as follows:[46]

March of Year	California sales in thousands of gallons[47]	Relative to March, 1941
1941	173,088	100
1942	200,625	116
1943	217,069	125
1944	320,052	185

The increase was especially rapid during the past year, so that by March of 1944 the domestic demand had increased 85 per cent from March of 1941. This rise in domestic demand was partly offset by a loss of export trade, and the relative increase of governmental demand in the other four states of the

43 Service Station News, April, 1944, p. 22.

44 U. S. Congress, Hearings on H. R. 58 (78th Cong.) Apr.-Dec. 1943, p. 397.

45 Thus proposals were made early in 1942 that California refiners run surplus gasoline back into the ground. This surplus condition was of relatively short duration.

46 From data supplied by Board of Equalization, State of California.

47 Net tax-paid sales plus sales to United States Government.

western area may not have been so great as that in California. It is nevertheless apparent that in 1944 the California industry was approaching the limit of its gasoline-producing capacity, and that further increases in military purchases would necessitate approximately equal reductions in civilian supplies.

The striking aspect of the wartime gasoline market situation, however, at least from the standpoint of postwar readjustment problems, is that over half of the total gasoline output is now being absorbed by military purchases, whereas civilian demand has declined only moderately below peacetime levels. The California industry is thus geared to the production of substantially more gasoline than a normal peacetime market is likely to absorb. This situation, together with an even greater overextension of fuel-oil producing capacity, promises to give rise to substantial problems in the reconversion period.

THE DEPLETION OF SURFACE STOCKS

The lag of production behind demand in the wartime expansion has led to a continual draft on the above-ground stocks of crude oil and refined products held by the industry. The decline in the total stocks of all petroleum in the Pacific Coast area from 1940 to date has been as follows:[48]

	Total stocks in thousands of barrels
December 1940	150,830
December 1941	141,677
December 1942	129,981
December 1943	102,597
March 1944	89,739

The net decline from December, 1940 to March, 1944 was about 61 million barrels, or approximately 40 per cent. This decline has not been distributed evenly, however, among all products. Residual fuel oil stocks have been drawn on very heavily, accounting for about 80 per cent of the total decrease in stocks; whereas the stocks of gasoline-bearing crude oil, gasoline, and Diesel fuel have not been so seriously reduced. Table 9 compares the stocks of the various products in March, 1944 with those on hand in December of 1940.

Several aspects of the resulting stock situation seem potentially significant. First, heavy fuel oil stocks are far below the level considered normal in the prewar period, and some replenishment of these stocks—although possibly not to the old level—is indicated when such replenishment becomes possible.[49] Second, the stocks of several other important products are down moderately, and will presumably be restored when this is feasible. Finally, the industry has currently available a very large volume of storage facilities which might be adapted to the storage of various products; storage facilities currently empty could absorb over two months' total crude production at present levels, or three months production at prewar levels. The industry is thus endowed with a large empty storage tank for use in the pursuit of short-run market stabilization after the war.

48 U. S. Bureau of Mines, California Petroleum Statement. 1940-1944.

49 The stocks of residual fuel oil and heavy crude oil (the equivalent of residual fuel) which were carried during the 1930's were probably somewhat larger than desirable or necessary; they had been accumulated because of the excessive production of such heavy products at various junctures, and were held from a market which already had an adequate supply at a low price. This policy of stock accumulation was fortuitously rewarded when the war period expanded fuel oil demand beyond current productive capacity. But it is unlikely that in the future fuel oil stocks will be deliberately raised to the prewar level

TABLE 9

Stocks of Principal Petroleum Products in the Pacific Coast Territory, December 1940 and March, 1944

Product	Stocks in Dec. 1940 (000 bbls.)	Stocks in Mar. 1944 (000 bbls.)	1944 stocks as percentage of 1940 stocks
Crude oil	35,816	31,803	89
Residual fuel oil	73,025	24,250	33
Gasoline	19,546	17,707	91
Diesel and gas oil	11,254	7,702	68
Lubricants	2,059	2,282	111
Natural gasoline	2,507	1,001	39
Asphalt	668	782	117
Kerosene	2,004	761	38
Other products	3,961	3,451	87
Total	150,830	89,739	60

Source: U. S. Bureau of Mines, California Petroleum Statements, 1940-1944.

CHANGE IN THE COMPETITIVE SITUATION

A final aspect of the war development which deserves some attention is its effect upon the character of competition within the industry. Any such effect, it should be noted, is likely to be latent rather than realized at the present time. Competition of the normal kind is suspended by the force of circumstances. With refined-product demand continually exceeding the supply, any and all refiners have in general had little difficulty in marketing all the output for the production of which they could obtain a raw material supply. Crude producers have been in a similarly favored situation. Prices have been stable at artificially low levels because of price control, and as a consequence there has been little cause for price instability. Finally, numerous "duration" arrangements for inter-company cooperation have been instituted, including extensive produce exchanges among companies which would normally compete in an active fashion. Competitive activity has been focussed principally upon the securing of government contracts, and the rapidly increasing demand has tended to keep even this kind of rivalry from becoming too severe.

Competition is currently changed, therefore, in that it is less serious and less intense. At the same time, certain changes have been taking place in the relative competitive potentials of various companies which promise to have some effect upon the character of industry competition when the demand situation becomes normal again and when wartime price controls are lifted. Most of the

changes in competitive potential are in the direction of some increase in the relative strength of the large integrated companies and of a corresponding weakening in the positions of the small independents--particularly the independent refiners. In short, there has been during the war some tendency toward an increasing concentration of control of the industry in the hands of the dominant major companies.[50]

This increase in the importance of the majors is reflected in some degree in the production of crude oil. Late data on production by companies are not available, but it is apparent that the major-company proportion of California crude-oil production has increased somewhat above the 50 per cent figure which obtained in 1940. This increase is principally due, however, to the release of previously shut-in production, which in the prewar period was held by the majors in larger proportion than actual production.[51] Perhaps of more importance in the long run is the fact that an increasing proportion of the crude-oil supply is being produced in the San Joaquin Valley and Coastal areas. The majors have substantial control of pipeline and tanker facilities running from these areas to the main refinery centers, and as a consequence are in a position to purchase practically all of the crude from these areas which they do not produce themselves.[52] A shift of the crude-producing center to the north, therefore, may in the long run lessen the ability of the many small independent refiners of the Los Angeles area to secure adequate supplies of crude oil (previously available in surplus quantity in the Los Angeles Basin) and may result in a weakening of their competitive position.

The principal change likely to be of immediate consequence in the postwar period, however, is in refinery capacity. The proportion of active distillation capacity controlled by the major companies (about 81 per cent) has, to be sure, not changed significantly during the war. On the other hand, at least 13 small independent refiners have gone out of business since 1940, their plants apparently going to scrap, and about 15 others will by the end of the war have been shut down for so long that it is probable that accumulated obsolescence and physical deterioration of their plants will prevent them from reopening.[53] If this is the case, the total number of small refiners, most of whom are located in Los Angeles, will have been reduced by 40 or 50 per cent, and the intensity of independent competition may at least temporarily be much less.[54]

A second change in the refinery market situation arises out of the construction of catalytic cracking and other aviation gasoline facilities during the war period. The very substantial addition to capacity in this line has been made entirely by the seven major companies and the two largest independent companies.[55] There are no recorded additions of this type of capacity by the thirty-odd remaining refiners still in operation. This development places the nine larger companies mentioned in a preferred position with respect to both quality and quantity of gasoline-producing equipment, and places the remaining firms in the industry much nearer to the limit of obsolescence. It may have a considerable effect upon the postwar competitive situation.[56]

50 For an analysis of the degree of concentration which existed in the prewar period, see Bain, op. cit., Ch. 3, 4, 5, 6.

51 Ibid. p. 43.

52 See Bain, op. cit., pp. 75-80.

53 U. S. Bureau of Mines, Petroleum Refiners..on the Pacific Coast, Jan. 1, 1941 and Oil and Gas Journal, April. 13, 1944. Sec. 2, pp. B-107-B-111.

54 The principal source of independent price-cutting competition in the past has been a group of small refiners operating small skimming plants in the Los Angeles Area. The roll of companies which have gone out of business or have been continually shut-down since 1940 includes a large proportion of these firms, which may now have made a permanent exit from the industry.

55 Oil and Gas Journal, Apr. 13, 1944 (pp. 158 ff.) lists the additions to cracking and aviation gasoline plant capacity by companies.

56 One independent refiner suggests that as the result of these new additions to capacity, the old skimming plant has become almost fully obsolete, and that small plants using older type cracking facilities (which put them in a preferred position before the war) will be the new marginal plants of the postwar period.

Currently, of course, it is also true that the major companies are controlling a somewhat larger proportion of the total sales of gasoline and other refined products than they did before the war. This is in turn partly attributable to their control of aviation gasoline plants, for the output of which the present military demand is so large. But it is more difficult to project this change than the more fundamental changes in competitive potentials referred to above. The principal latent effect of the war period on competition seems to inhere in increasing major control of new-type refinery capacity and in the realized or pending exit from the industry of a considerable number of small refiners.

So much for the prewar situation in the California petroleum industry and for the changes which have been effected by the war until the middle of 1944. We now turn to our final task, an analysis of the probable postwar condition of the industry.

CHAPTER IV

POSTWAR PROSPECTS

ASSUMPTIONS UNDERLYING OUR POSTWAR PREDICTIONS

No prediction of conditions in the postwar period is particularly meaningful unless it distinguishes among several consecutive time intervals which will follow the war. Economic predictions generally must differentiate the demobilization and reconversion period, the secondary postwar period of "return to normalcy," and the longer pull following full readjustment to the secondary consequences of the war.[1] This distinction is especially relevant in the case of the petroleum industry, where the relationship of supply to demand is likely to change considerably as we pass from one of these periods to another. As a consequence, we will discuss the postwar prospects of the California oil industry in each of these three intervals separately.

As a basis for postwar predictions, it is appropriate to make some assumptions concerning the duration of the war or wars in which we are now engaged. In calculating the future of the Pacific Coast petroleum industry, the most relevant date is presumably that of the end of the Japanese war, which will evidently occur after the end of the European action. As long as the Pacific war is in progress, the California oil industry appears likely to remain under a draft at least as heavy as at present. The termination of the European war may result in some cutback of West Coast munitions production and may allow some petroleum to be diverted from other areas to meet military demands which are at present borne by the California industry. But it seems doubtful that the net effect on this industry in the interval between the first and the second armistice will be sufficient to cause a serious readjustment. At any rate, such change as may be effected is so uncertain that prediction is fruitless.

We will not draw our assumptions, therefore, in such fashion as to recognize for purpose of analysis a separate inter-armistice period. Nor will we attempt to predict the calendar date of the end of either "half" of the present war. We will, however, make two assumptions as a basis for prediction. First, both the European and Japanese wars will be concluded before the current productive potential of California oil fields is seriously altered, either downward by exhaustion of reserves or upward by major new discoveries. We thus (by assumption) enter the prewar period in the currently prevailing supply situation. Second, the Japanese war will be over soon enough after the end of the European war that an interim period with distinctive properties will not have time to develop. In effect, the wartime demand situation is assumed to remain fundamentally unaltered until the end of the Japanese war, so that the initial readjustment period is coincident with a general return to peace, involving general demobilization, great curtailment of

1 This trichotomy is a conventional one for dealing with business-cycle problems in inter-war periods. That is, we distinguish the primary postwar boom and collapse, the secondary postwar expansion, the severe secondary postwar depression and the aftermath of this depression. The problem at hand is not primarily a cycle problem, but the same division of time seems appropriate.

military requirements for all goods, and severe reduction of munitions production.

The first period to be considered may then be designated the immediate postwar period or the interval of primary postwar readjustment. It is defined as follows. Beginning with the end of the war, it includes the period during which the bulk of the armed forces are returning to this country and being demobilized, and also during which munitions production is abandoned and industry is reconverted to civilian-goods production. During this period there may be large outshipments of many goods for relief purposes, but it is assumed that the normal export trade of the California petroleum industry--which before the war centered in the western Pacific--will not yet have been resumed. Another aspect of this primary postwar period relevant to the welfare of the petroleum industry is that the stock of automobiles in use will presumably have been less than fully replaced before the end of the period. The interval ends when demobilization has been effected, industry has been substantially reconverted, the stock of automobiles is approaching normal, and export trade in oil has been resumed in whatever form and volume conditions may allow. The end of this interval is tentatively set at from 12 to 18 months after the close of the Japanese war.

The period of secondary postwar readjustment begins as the interval just described draws to a close.[2] It is arbitrarily[3] defined as having a duration of from six to ten years, and should include the secondary postwar prosperity[4] and whatever secondary postwar depression is permitted to develop. The "long pull" period refers to the two or three-decade interval following the end of the secondary postwar adjustment period. We turn first, however, to the period of primary postwar readjustment.

THE IMMEDIATE POSTWAR PERIOD

The problem of the California petroleum industry in this initial period promises to be one principally of short-run readjustment toward the establishment of a new market balance. The interval will be too short for the crude oil reserve situation to undergo a significant degree of change or for technological or locational influences to affect seriously the conditions of supply and demand. What the period will involve is first a substitution of peacetime for wartime conditions of demand and second an adaptation of supply to the new demand conditions. This is the initial bridge which the industry will have to cross. In order to calculate the character of the crossing we need first to estimate demand and supply conditions in the postwar period.

The basic factors which influence the demand for petroleum products in the contemporary economy are the volume of domestic industrial and heavy transport activity, which determines the requirement for fuel oil; the stock of useable motor vehicles, which co-determines potential demand for gasoline; the volume of direct military requirements, especially those for gasoline; and the level of export requirements. In the reconversion what will be the state of these determining factors on the west coast?

First, it seems likely that industrial activity will be severely curtailed. Munitions production will be heavily cut back, and whatever the industrial

2 In fact, of course, we will pass gradually from the first interval into the second.

3 The definition is arbitrary in the sense that the choice of any length for such an interval must be arbitrary, but the choice is not simply random in character. Six to ten years is the most probable length of the first complete postwar business cycle.

4 Corresponding, perhaps, to the period from 1921 to 1929.

future of the Far West may be, industrial activity will not reapproach wartime levels during this reconversion period. Rail traffic depends in part on industrial activity and thus should also feel an adverse virtual effect. The place of the Pacific Coast as a debarkation area for returning troops and matériel from the Pacific area, on the other hand, will presumably tend to sustain rail traffic for at least a year, so that the net reduction in this activity should be smaller than that in industrial production.

Second, it seems probable that during this period the stock of motor vehicles in the western area will be somewhat subnormal, averaging at least 10 per cent below the level of 1941. This is the predictable outcome if the present rate of decline in the number of useable vehicles continues until automobile production is resumed, and if the resumption of such production is delayed (as anticipated) about six months after the close of the war.

Third, it is estimated that direct military requirements for gasoline and other products will be reduced by at least three-fourths from the current levels. This is a rough estimate, and it is not possible to obtain reliable data upon the basis of which it could be made more precise. Even if large garrison and occupational forces are maintained, however, it seems a priori improbable that immediate postwar military demand will exceed one-fourth the present level.

Finally, it is assumed that export requirements during this period will be small, not exceeding 10 per cent of the total demand. This assumption seems justified by the fact that the principle visible peace-time outlet for California exports in recent times has been Japan, and that such exports are not likely to be resumed in volume during the first year of peace.

The effect of these changes on the net demand for refined products may be estimated somewhat as follows. In the first place, the total demand for fuel oil during the reconversion period should be substantially below the 1943 and 1944 levels. Fuel oil demand early in 1944 was in the neighborhood of from 475,000 to 500,000 barrels per day, whereas the 1941 average demand had been only 286,000 barrels.[5] This increase, as we have indicated, has been due primarily to the great expansion in munitions output and to a terrific increase in railroad traffic. With activity in both of these lines, at least temporarily restricted, it seems probable that reconversion-period demand for fuel oil will lie somewhere between 275,000 and 350,000 barrels per day, and that it is most likely to be at or slightly above the 1941 level of demand. Any more precise estimate than this does not seem justified at the present writing.

The total demand for gasoline will be made up of a civilian and a military component. Because of the progressive reduction in the total number of useable vehicles in the Pacific Coast area, it is doubtful that during the reconversion period the civilian demand for gasoline will exceed the 1940 level of about 175,000 barrels per day. Such a demand would represent an increase of about 15 per cent over the current volume of civilian use under rationing. In view of the liberality of current rations to a considerable part of automobile users, and in view of the poor average mechanical condition of the automobile stock during the reconversion period, the prediction of so small an increase does not seem unreasonable. Even an optimistic estimate, in any event, could hardly place civilian gasoline demand above 190,000 barrels per day in the reconversion period. The export demand for gasoline (which was about 35,000 barrels per day in 1940) will presumably be smaller during this period. Finally the

5 U. S. Bureau of Mines, California Petroleum Statements, 1941, 1944.

military demand for gasoline, which is currently about 160,000 barrels per day, will probably not exceed 40,000 barrels. If the preceding estimates are combined, they aggregate gasoline demand during reconversion at about 230,000 barrels per day, and the maximum demand at 250,000 barrels. The mean estimate is again very close to the total demand figure of 1941, which was 235,000 barrels per day.

The demands for two principal products—gasoline and fuel oil—thus promise to recede to about the 1941 level. Without making detailed estimates for the less important products, we may suggest that on the average this will also be the case for them.[6] The aggregate demand for refined products should then also fall to its 1941 value—about 700,000 barrels per day. Deviations of actual experience from this estimate seem somewhat more likely to be down than upward—a total demand of 676,000 barrels per day, such as obtained in 1940, is quite conceivable. So far as it can be anticipated, moreover, the composition of the total demand should not be greatly different than it was in 1941, and should thus reflect some correction of the wartime distortion in the pattern of demand.

This total demand, which would be approximately 30 per cent below that of early 1944, would create a need for about 700,000 barrels per day of crude oil and natural gasoline, or about 650,000 barrels of crude alone. What of the crude oil supply available to meet this demand? Current crude oil production is in the neighborhood of 850,000 barrels daily, considerably in excess of estimated immediate postwar demand. To get this production, however, California oil fields are being operated at approximately full capacity, and there is not a significant gap between sustainable potential production and actual production. If this situation still obtains at the end of the war, the prevailing potential production will actually be lower than it apparently was in 1940 and 1941, when it was calculated at about 1,000,000 barrels daily.[7] Although some curtailment of production below attainable levels will be required to match supply with demand, it will presumably be a lesser degree of curtailment than that under which the industry was voluntarily operating in 1940.[8] The immediate supply-demand situation after the war should therefore not be greatly different than it was in the prewar period. Potential supply will exceed demand, but a feasible degree of curtailment, made effective through long-accepted proration techniques, should be sufficient to equate demand and supply at customary levels of crude price.

The only serious difficulty which may be encountered in thus adjusting supply to demand is that crude oil producers, after several war years of relatively unrestricted production, may be unwilling immediately to enter upon a severe curtailment program. If a period is required in which to persuade producers to return to curtailment, some cushion will be provided by emptied storage tanks, which can absorb a margin of overproduction for several months. Continuation of production at wartime levels, however, would very soon create a large oversupply of crude and would lead to demoralization of the domestic market, to heavy export dumping, or to both. There is therefore a very strong argument for reinstitution immediately at the close of the war of an adequate curtailment policy. This policy may be

6 For the two remaining products which are produced in significant volume—Diesel and gas oil and asphalt—such an estimate is consistent with our general supposition concerning the level of industrial activity.

7 See p. 14 above.

8 In 1940, production was curtailed to about 60 per cent of the sustainable potential production, whereas in the immediate postwar period our estimates indicate a curtailment only to about 75 per cent of the probable potential.

sponsored either by the federal government, if it temporarily extends its wartime controls, or, if government controls are dropped, by the voluntary proration committee of the industry, but it should in one way or another be adopted. Immediate reinstitution of severe curtailment is necessary not only in order to stabilize the market, but also in order to conserve the scarce reserves of oil.[9]

The ability of California to carry through proper curtailment measures is of course conditioned by the parallel action in this regard of other oil-producing states. Since most of these states have a considerable proration history, however, it is probable that they also will pursue intelligent postwar curtailment measures and that the California demand and supply can be effectively and fully balanced.[10]

The basic overall supply of crude, and therefore of refined products, can thus be correctly adjusted to the immediate postwar change in demand. Any influence which may be brought to bear upon the supply situation by the quantity and quality of refinery equipment will necessarily affect only the composition of this total output and its allocation among the various firms in the industry. If the preceding estimates of total demand and total crude oil output are correct, the immediate postwar period will witness a considerable degree of excess capacity in refinery plant and a large amount of shut-down plant. At least 20 per cent of basic distillation capacity will be shut down, and the remainder will operate at somewhat less than the maximum rate. Because total distillation capacity in the industry has not increased significantly during the war, however, the overcapacity in this type of equipment should be no more serious than it was in the immediate prewar period.[11] The increase in cracking capacity, however, has been much larger, amounting to about 40 per cent of 1940 capacity. If in the immediate postwar period there is a 15 to 20 per cent reduction of gasoline demand below the wartime level, there will presumably be a large amount of excess and shut-down cracking capacity. This may amount to as much as 40 per cent of all such capacity in the industry, whereas only about 20 per cent of cracking facilities were shut down at the end of 1940. Such a high degree of enforced idleness of cracking plant will follow not only from the reduced need for gasoline, but also from the absolute lack of sufficient charging stock to keep all cracking facilities operating.[12] The immediate demand situation will probably not be such, moreover, as to favor the extensive use of cracking facilities either to produce higher than prewar proportions of gasoline from crude oil or to produce very great amounts of especially high octane fuel.[13] Whether this redundancy of plant will have its principal impact upon the older type thermal cracking or the new catalytic cracking plants, is difficult to say, but it will certainly place some financial strain on the refining industry.

9 After more than ten years of relatively successful proration operations under its "voluntary" plan, from 1930 to 1940, the California industry should be adequately prepared to reinstitute curtailment as required. No additions to the existing legal framework seem essential to the accomplishment of this end.

10 See Northcutt Ely, "The Conservation of Oil", Harvard Law Review, May, 1938, pp. 1209-1244, for a general description of state conservation measures throughout the United States.

11 Such overcapacity before the war did contribute to latent competitive instability in the gasoline market, and this effect may recur.

12 Cracking facilities are ordinarily charged with gas oils or fuel oils obtained from distillation, and the quantity of such oils available depends strictly upon the quantity of crude being distilled. One source (Moore and Elder, National Petroleum News, June 7, 1944, pp. R-334 ff.) estimates that with crude production and distillation at the 1940 rate, there would be from 40 to 53 per cent idle capacity in catalytic cracking and from 52 to 57 per cent idle capacity in thermal cracking. According to our estimates, which involve crude production slightly above the 1940 level, the proportion of idle to active cracking plant would be slightly less than the preceding estimate.

13 Cf. A. L. Foster, on postwar refining processes in Oil and Gas Journal, April 13, 1944, pp. 189 ff.

An additional effect of the potentially high degree of excess capacity in cracking plant may be that it will tend to intensify competition within the refinery market. If 40 per cent of cracking plant is to be idle, the question arises as to what firms will hold the idle plant and in what proportions. If this problem is not settled by agreement or by mutual restraint, severe price competition in the gasoline market may tend to emerge, and to no particular end, since a substantial amount of plant will be unalterably redundant. Should severe competition result, the major companies as a group are in a technically superior position, having the bulk of the new-type plant, but there is no reason to believe that in the short period this will enable them to drive independent capacity to cover. A potentially unstable condition in the refinery market therefore portends for the immediate postwar period; what the actual result will be depends upon the character of measures taken by the firms of the industry collectively or individually to forestall market instability.

In short, the primary problem which is posed in the immediate postwar period is one of market adjustment to a declining demand. The immediate difficulty will evidently be one of surplus, both in crude production capacity and in refining capacity. The potential surplus of crude oil, however, is susceptible of effective elimination through established control measures, and there is little danger of these measures not being used effectively. Provided that a crude oil surplus is avoided, the surplus of refinery capacity will simply be reflected in idle plant. Its most serious possible consequence would be the creation of competitive instability in the refined-product markets, but such instability is by no means certain to emerge.

So far as the prospects for the creation of employment and income <u>within</u> the petroleum industry go, it is clear that these are directly dependent upon the general rate of industrial and transport activity along the Pacific Coast. In terms of the probable rates of such activity suggested above, it would appear that employment and income in the Southern California petroleum industry during the reconversion period probably will not exceed the 1941 level (except so far as adjustment may be made for a generally higher price level). Current output should approximate its 1941 value, and the rate of investment in new plant, after the wartime construction spree, will probably be small. Certainly the petroleum industry is not to be regarded as a dynamic factor in the postwar reconversion situation. By properly controlling its output, however, it may contribute to the stability of this period.

THE PERIOD OF SECONDARY POSTWAR READJUSTMENT

In the six to ten years which follow the end of the reconversion period the problems encountered in the California petroleum industry are likely to be of a different character. There is continually, of course, a problem of year-to-year adjustment of supply to demand, but under ordinary circumstances the industry seems able to deal effectively with this problem. The more pressing question as we contemplate a future interval as long as a decade concerns first the probable secular development of overall demand and of its various components, and second the ability of the industry to meet this developing demand without increases in price. An attempt to answer this question involves an inquiry first into whether the size of the California oil industry—in Los Angeles and elsewhere in the state—will increase, remain stable, or decline; and second into whether the industry will be able to support an economy and industrial effort on the Pacific Coast of the present, a smaller, or a larger magnitude.

The problem may be approached in three stages. First, we may calculate the probable secular increase in demand on the assumption that a supply to match it is forthcoming at the same general level of relative prices (i.e., with appropriate allowances for a general change in the price level) which prevailed before the war. Second, we may estimate the probably evolution of supply conditions in response to the assumed changes in demand, over the interval in question. Finally, we may revise our estimates of demand in the light of any observed shortage in local supply, and infer the probable net effect on the industrial development of the West Coast area. This same general procedure is appropriate in analyzing both the short-run and the long-run development of the industry; but we will turn first to the immediate postwar decade.

It is not the purpose of this study to prognosticate the future increase of Los Angeles, California, or Pacific Coast population. The present writer is not aware of any method of predicting such increases which will yield estimates the likely errors in which will be less than 50 per cent of the predicted increases. This is true not so much because of some general uncertainty regarding all future population, but particularly because the future development of the west is affected by a large number of specific imponderables, including the course of economic development in the Orient, the importance with which people will in the future regard climate as an economic good, the rate of development of the aircraft industry, the policy of the Interstate Commerce Commission in setting transcontinental rail rates, and the geographic pricing policies of the large industrial firms of the United States. About all we can do for the purpose of the present prognosis is to postulate some possible or probable future development and to examine its implications in terms of the demand for and supply of oil.

As a basis for the following analysis, therefore, we will suppose two alternative situations with respect to population. We will assume, first, maintenance of population and industrial activity on the Pacific Coast at the same levels which obtained in the prewar period, and second, a retained increase in population and in industrial activity sufficient to create for petroleum products a general level of demand equal to that reached in the year 1943.

The actual course of events in the first postwar decade may well lie somewhere between these limits. In spite of withdrawals to the armed forces of nearly 10 per cent of the prewar population, the Pacific Coast states have experienced a substantial net increase in civilian population since 1940, principally because of the in-migration of workers to shipyards and airplane plants, and also through the shift of the families of service personnel to this area. In California the net increase amounted to about 650,000, or 10 per cent of the prewar population, from 1940 to 1943. Retention of such increases, together with the normal return of service personnel after the war, would certainly permit (although not necessarily assure) maintenance of the regional demand for petroleum products at or above the 1943 level. For any important proportion of this population increase to be retained, however, or for it to be effective as a source of petroleum demand, industrial activity must be sustained to provide it with employment and income. Since the degree to which such industrial activity will be present is quite uncertain, either on the Pacific Coast generally or in particular localities within the area, it seems wise also to entertain the possibility of a petroleum demand somewhere between the 1940 and the 1943 level.

The Pacific Coast demand for petroleum products in the prewar period, described in detail above,[14] serves as a prototype of the smaller postwar demand. In the second situation assumed, there would be a general expansion of demand to the level of about 900,000 barrels per day of all products; this would require a daily output, let us say, of about 825,000 barrels of crude oil and 75,000 barrels of natural gasoline. Such a level of demand would be about 28½ per cent above that of 1941 or 33 per cent above that of 1940. Its development, however, would not necessarily entail a proportional increase in population over those base dates, since it could be accomplished in large part by a general acceleration of peacetime industrial activity with only a slight retained increase in population, together with a rise in the number of automobiles in use and in annual mileage per automobile.[15] It is certainly conceivable that such an increase in demand may take place during the next decade, although it is recognized that it would be attained gradually rather than all at once.

The change in the composition of this or a smaller demand which would occur with the passage of time is rather uncertain. If currently known techniques are employed, a general industrial expansion would involve at least proportionate increases in the requirements for fuel oil (and for natural gas) as long as these goods were available at low prices. When a general economic expansion occurs, therefore, it is likely to be desirable to expand the production of residual fuel oil at the same rate as that of other products. If the industry should be unable to effect such an increase, either because of crude shortage or because of a disproportionately large increase in the demand for other products, there would presumably be a relative rise in fuel oil prices and some adjustment away from the use of petroleum as an industrial fuel. The future course of gasoline demand is less certain. Informed persons generally agree that there will be a substantial improvement in the quality of gasoline in the postwar period, made possible through the use of new cracking and other processes. But there is less certainty as to whether automobile design will be modified so as to effect great economies in the use of gasoline, and whether aircraft demands for gasoline will come to represent a significant proportion of the total peacetime demand.[16] We may hazard, however, the guess that as long as gasoline prices do not increase greatly,[17] low-horsepower engines will not be generally adopted by the automotive industry, and present rates of fuel consumption per mile of travel will not be substantially improved. If this is the case, gasoline demand will probably expand proportionately with that of other products, and no major upset in the past patterns of refined product demand will result.

There is to be sure some prospect of an increased use of refinery by-products in the chemical industries, including the manufactures of synthetic rubbers and plastics. California, like any other petroleum-producing area, may attract such industries in due proportion to its petroleum output, and these industries may create an attractive additional market for local petroleum products. So far as can be ascertained, however, California will compete on no better than an equal footing with Texas and the Midwest for the custom of such industries.

14 See above, p. 9.

15 The requisite rate of increase in both of these items would of course vary inversely with the size of the realized export demand.

16 It is generally recognized that it is possible to build lightweight, low-horsepower automobiles which would at least double the passenger miles of transportation per gallon of gasoline obtained with present American care, but the introduction of such automobiles on a wide scale would be contingent jointly upon a change in consumer tastes, a concerted change in the product and sales policies of the large automobile concerns, and a "forcing" change in the price of gasoline. If such a general change were adopted, we could expect a substantial reduction of automotive demand for gasoline. Aircraft demand for gasoline (barring military demands of wartime size) is not likely to be a major factor unless the use of aircraft extends beyond the commercial stage on a large scale.

17 And we for the present assume they will not.

In estimating the probable proportion of such synthetics industries which may locate in California, it is well to recall that in 1943 California had 19 per cent of the national oil production, 17 per cent of the discovered oil reserves, and about 5 per cent of the national population. In general, we may expect that the revision in the total demand pattern which results from the rise of synthetics industries will not be revolutionary.

With respect to the pattern of demand, therefore, aside from its overall volume, it appears that no substantial changes are in definite prospect in the first postwar decade. We will consequently postulate that, in the absence of a basic shortage of crude supply and a corresponding general price revision, the various refined products will continue to be demanded in about their present proportions.

Assuming this, let us consider the two suggested overall demand situations suggested above--one requiring a crude oil production of 650,000 barrels per day, and the other requiring an output of 825,000 barrels daily. How well will the California industry be able to meet these demands for the next ten years?

We have already advanced the assumption that at the end of the war the California industry will have a current productive capacity of about 850,000 barrels of crude per day. This does not mean, however, that it can automatically sustain this capacity for ten or even for five years. The present known recoverable reserve would be completely depleted in ten years of production at the 825,000 barrel rate, or in thirteen years at the rate of 650,000 barrels per day. This in effect further implies that production from these reserves could not be sustained at either stated rate for the entire period necessary fully to deplete them. Production can be drawn from a limited reserve only at a decreasing rate; although the present reserves should eventually provide the equivalent of ten years' supply at 825,000 barrels per day, they could supply it only at a steadily diminishing rate over several decades. If they were so operated as to keep production equal to the maximum attainable economic rate from this point on, this maximum rate would probably have declined at least 50 per cent at the end of the first decade.

The ability of the California industry to sustain any given production rate for a decade therefore depends jointly upon the size of the known reserves, the initial size of the drilled or drillable potential production, the actual rate of production desired, and the rate of new discoveries. As of the present date we have some idea of all the needed data except one item. Known recoverable reserves are about 3,337 million barrels of crude.[18] The current potential is about 850,000 barrels per day,[19] and this may be temporarily expandable through further drilling of known reserves to about 900,000 barrels daily. The future rate of production is for the purposes of our problem an arbitary item which we may assume to lie at various levels in order to determine the ability of the industry to sustain these levels for a decade. The strategic unknown is the future discovery rate.

As indicated above, it is impossible to predict this discovery rate with any accuracy whatever, but the experience in California since 1938 justifies pessimism with respect to its future.[20] No important new discovery has been made since that time, and the assortment of small discoveries made during the war period has failed to reveal any attractive new horizons for the finding of large quantities of oil. Recognizing always that a great new bonanza might upset our calculations (an event most sincerely to be hoped for) let us

18 See pp. 15-17 above.

19 See p. 14 above.

20 See p. 16 above.

investigate the immediate productive future of the California industry in the event that the discovery rate is inadequate, small, or negligible.

At one extreme let us suppose that no new discoveries are made from the end of the war onward. What is the ability of the industry to produce from currently known reserves: first at a daily rate of 825,000 barrels, and second at a daily rate of 650,000 barrels? It seems definite and clear that a rate of 825,000 barrels could hardly be maintained for a decade. The potential would certainly drop below this level within five years and would be considerably below it by the end of ten. With currently known reserves, the California industry would be definitely unable to sustain by itself the higher rate of industrial activity which would create the demand for this quantity of oil. It is also unlikely that with known reserves we could sustain 650,000 barrels of daily output for a decade. Such a rate would leave only about half of the current recoverable reserve underground at the end of six and one-half years, and it is questionable that this remainder would yield currently at the 650,000 barrel rate. In the absence of new discoveries, therefore, it is doubtful that the California industry alone could sustain the 1941 level of activity for a decade.[21]

At another extreme, let us suppose that the discovery record is fairly favorable--that is, it is on the average as good as that of the decade from 1931 through 1940. During that past period, a recoverable reserve of 2,073 million barrels was discovered, and this was sufficient, with the relatively low level of output which characterized the 1930's, almost exactly to offset total production and to maintain the level of untapped reserves through the decade.[22] It would be extremely optimistic to predict a higher discovery rate than this for the first postwar decade in California.

Such a rate of discovery for ten years would be sufficient to replace almost nine years' production at the rate of 650,000 barrels per day or less than seven years' production at the 825,000 barrel rate. Even with discoveries as large as those of the 1930's, therefore, either of these rates of production would result in some net depletion of remaining recoverable reserves in California. On the other hand, such a discovery rate, if fortuitously timed, should enable the California industry to maintain either production rate for as long as a decade. It would, in other words, continually replenish the potential productive capacity enough that an 825,000 barrel rate could be maintained throughout the period, even though the undepleted reserve was slowly shrinking.

The resulting discoveries, however, would be none too large to allow for this result. It follows that even with an average rate of discovery equal to that attained in the 1930's, the California industry could not well support a demand substantially above the 825,000 barrel level, and that with a smaller discovery rate the maximum sustainable production would fall below this level.

A conservative estimate would certainly place postwar discoveries at a rate below that attained in the decade from 1931 to 1940. Let us take half of that rate as a mean working estimate. If this prediction were approximately realized, several consequences would ensue. First, the California industry could not sustain a crude output of 825,000 barrels per day for a decade. It

21 It is recognized, of course, that the rate at which a dwindling reserve can be produced depends not only on physical factors, but also upon the degree of expense and effort undertaken to sustain production. The preceding estimates assume the probable degree of intensity of exploitation which profit-seeking companies are likely to undertake.

22 See p. 8 above.

would fall below this rate by the end of the first five years and would decline slowly but steadily from that point for the rest of the period.[23] Second, the industry could just about sustain a rate of 650,000 barrels per day--a prosperous prewar level--for ten years. Even this production rate, however, in conjunction with the assumed discovery rate, would involve reducing the remaining recoverable reserve by more than half and would presage an early severe decline in the California industry.

Taking the probabilities of discovery into account, then, the general supply prospect in California for the postwar decade may be summarized as follows. With fair success in discoveries, the producing industry of the state will be able for ten years to support a postwar demand as large as that of the year 1941. But in the absence of definitely good success with discovery it will not be able to support a substantially higher level of demand than this, nor to service industrial activity at a markedly higher level. A discovery rate as high as that of the 1930's would be required to sustain activity at the wartime level even temporarily, and an unprecedented discovery rate (for this area) to sustain a demand substantially above the wartime level.

There is thus evidently no certainty that supply and demand will balance at the customary level of relative prices during the first postwar decade. If the Pacific Coast economy does not experience much net expansion during this period, to be sure, so that demand does not greatly exceed the 1941 level, no serious problem of readjustment may be raised. If, on the other hand, there is a substantial expansion, readjustments are definitely in prospect. The common expectation when demand exceeds supply at a customary price is that the price will rise. The increase in price is supposed ordinarily to result in some reduction of the amount demanded and some addition to the amount supplied, and to proceed to the point where demand and supply are in balance. This will evidently happen in the event of a crude oil shortage in California, but the prospect of such an adjustment is in itself no assurance. Two important further issues are in fact raised by the prospect of increasing crude prices. First, in what degree will the rise of crude prices increase the supply, and what will be the source of the increase. Second, in what degree will the price increase restrict demand, for what particular refined products will it restrict demand, and what will be the impact of these restrictions on the level of economic activity in the California orbit?

Turning first to supply, it is apparent that moderate increases in price will not with any certainty elicit a larger production within the California area. Such increases may intensify the exploitation of existing reserves and may somewhat postpone the abandonment of marginal wells and fields, but neither of these expedients will greatly increase recovery over an average of ten years.[24] New discoveries are essential, and these by their nature cannot respond in any definite way to price changes. The rate of exploratory activity may respond, but rewards are not proportional to efforts in such activity. All that a price increase can do, therefore, is to improve the probability of new discoveries; it may not result in any actual discoveries at all. We cannot therefore depend upon the rise in California prices to overcome the crude shortage by stimulating local production. The basic long-run crude supply is evidently fairly inelastic to price changes of a moderate degree.[25]

23 This on the assumption of a steady or constant rate of discoveries throughout the period.

24 A very large number of wells are in the so-called "stripper well" category, and with declining reserves an increasing proportion of all wells will fall in this category. The effect of a moderate price increase on the total production brought from all stripper wells, however, would not be large enough to affect the overall supply situation greatly.

25 Major waves of discovery seem to have occurred more as the result of the introduction of new exploratory techniques than as the consequence of accelerated exploratory activity or high crude prices per se. It is therefore extremely hazardous to postulate any significant association between crude prices and major discoveries.

On the other hand, price increases up to a given level will increase the local supply by attracting imports from other areas--in the case of California most probably from the Texas Gulf Coast. As soon as the California price exceeds the Texas price by the amount of water freight from Texas (at least 50 cents per barrel of crude), Texas crude will flow in, presumably in a quantity sufficient to overcome the shortage and to preclude further increases in price.[26] This is in fact the probable development in California if local crude supplies become short relative to demand. Price would rise to the import limit without greatly increasing the local supply, and at that point Texas crude would make up the local deficit. (Since Texas is currently the great surplus area in the United States, it should be able to meet such a demand during the next decade without significant increases in its relative crude prices.) California prices are currently somewhat above those in Texas. A California shortage would therefore probably induce a rise of from 30 to 40 cents in the California price per barrel of crude, at which point California would become a net importing area. The absolute increase in price would be moderate, but California would then be at a distinct relative price disadvantage to Texas as a general source of supply for petroleum products. Such a development in the next decade seems definitely in prospect if the West experiences the often-predicted great development in population and in industry.

Would such a price increase have a large effect on the level of demand for petroleum products on the West Coast? This is the serious question, for if it would, it is implied that a local shortage of petroleum would retard any anticipated large increase of population and industry in the Pacific Coast area.

It appears that a price increase of the magnitude mentioned might have a perceptible retarding effect on the total demand for refined products in California. This is not so much the case with gasoline demand, which would presumably be little affected by a moderate price increase. Fuel oil demand in a given area, on the other hand, is potentially more elastic to price changes, first because substitute fuels may be available and second because other areas with cheaper fuels are available as sites for industrial activity. The price increase in fuel oil which would correspond to the crude price increase mentioned would thus presumably retard somewhat the use of fuel oil by existing industries in the West and might also discourage the establishment of new industries which could be based on the use of residual petroleum products as fuel.[27]

The net effect of such a change in fuel oil prices on the level of fuel oil demand in the California area will depend first on the effect on the costs of production incurred by industries using fuel oil of a price differential of perhaps 50 cents per barrel of the product (as compared with Texas or the Midwest) and second on how many compensating advantages for industrial location the California area can offer. Determination of these matters lies outside the scope of the present paper, and we will be content with the observation that the emergence of a local crude shortage will create a disadvantage for California as an industrial area which will have to be overcome if the state is to support a large industrial development.

Presuming that this disadvantage is overcome, so that petroleum demand in the Pacific Coast area rises to the 825,000 barrels per day level (or higher) in spite of a relative price increase, and presuming that the future discovery

26 Cf. Bain, op. cit., pp. 15-22.

27 The retardant effect would be felt principally in those industries which use fuel oil or natural gas for industrial heat, and for which the cost of such heat is an important item in industrial expense. It would be effective so far as the local shortage of fuel oil was matched by a corresponding relative shortage of natural gas.

rate is low, the prospect for the next decade would be that California would become increasingly an oil-importing area. The local producing industry would supply from 600,000 to 650,000 barrels per day of the total (depending upon the curtailment policy followed) and imports of from 175,000 to 225,000 barrels daily would make up the difference.

If the area can continue to attract demand [28] at a higher price, therefore, industrial development will not be retarded. The local petroleum producing industry should be able for a decade to maintain roughly its prewar level of production. The refining industry, on the other hand, should be able to expand (or fully to utilize its currently expanded facilities) by processing the entire local crude output plus the imported addition to this output.[29] A general expansion in sectors of the industry other than that engaged in crude production is thus in prospect, provided, of course, that any price increase consequent upon a local crude shortage does not retard general economic expansion.

The preceding applies to the potential development of California as a whole. What of the specific effect of the predicted developments on the Southern California area? As indicated in a preceding section, the Los Angeles basin is apparently the declining area in California in point of crude production. With any probable rate of production in the next decade, Los Angeles is likely to lead the decline in California production, so that its crude output will become absolutely and relatively smaller than in the past. This should not, however, presage a corresponding decline in its refining industry. Refineries are naturally tied to markets and general industrial areas, and once established are not readily moved. Since the California refinery industry is already centered in Los Angeles, and since Los Angeles is the principal California market, with an attractive tidewater location for industrial production, it should be able to retain its dominance in refining. As Los Angeles crude output declines, the area should draw crude supplies from the San Joaquin and Coastal fields, or from Texas and other outside points when overall demand warrants this. The decline of its crude-producing industry, on the other hand, is in itself a matter of some consequence, and will have to be counted as a net loss to the regional economy.

The principal limitation on the industrial development of Los Angeles which would be consequent upon a growing shortage of crude in Southern California or in California generally, therefore, would not primarily be the competition of other sites in California. The Valley and Coastal areas do not offer such attractive locations for general industry, and the San Francisco Bay area has no net advantage in importing crude from Valley, Coastal, or outside points. The main limitation is the competition of areas outside California which may be able to offer petroleum fuels at a lower price or other fuels at a lower cost per unit of heat or power. In the succeeding decade, the failure to discover large additional crude supplies in California would make this competition effective, and would in some degree retard California and Southern California development. Whether this drag on development would be serious is a matter for speculation and further analysis.

THE LONG-RUN PROBLEM

In speaking of possible developments in the California oil industry during the first postwar decade, we have essentially posed a problem susceptible to

28 That is, if the growth of population and industry in the California area is not retarded by the relatively unfavorable price for refined products—especially for fuel oil.

29 It is economically feasible to import a crude oil supply to a market area and refine it there. This is the general practice on the Atlantic seaboard and in the Great Lakes area at present.

statement in two ways. First, what will be the probable effect on California economy if demand in this area becomes so related to domestic supply that California becomes an oil-importing area? Or second, what are the probable consequences of a situation in which California oil production declines more rapidly, relative to local demand, than the world supply declines relative to the world demand? It has been indicated that a situation which might be described in either of the preceding manners is possibly in prospect in the next ten years--that is, the Texas and Midwest supply in this country together with world supplies elsewhere may continue for a time to be adequate to meet total world demands without a substantial general price increase, whereas the California supply may be insufficient to meet a rapidly growing local demand. Such a development has been postulated and the general character of its probable consequences examined.

In what wise does the long run problem of the California petroleum industry and of the regional economy which depends upon it differ from that posed for the next decade? It differs generally in that in the long run we face not the problem of a local shortage of supply relative to local demand, but one of a world shortage relative to world demand. It is of course difficult to predict when this general shortage will begin to be felt, since there is much unexplored territory on the globe and a definite possibility of great discoveries in the future. Demand, however, is large and increasing, and presently known world reserves will apparently not support the probable demand for as long as 25 more years.[30] It does not seem unduly pessimistic to suppose that within 25 years, even allowing for additional discoveries, petroleum production may become so short relative to demand as to lead to a major upward price adjustment. It is a priori certain that at some time within the generally predictable future such a result will ensue. Petroleum is a strictly limited and exhaustible resource (except in terms of geologic time intervals) and is bound to be relatively exhausted before too long.

The long-run problem which California or any other oil economy faces, therefore, is the impact of a general oil shortage sufficient to lead to a major upward adjustment in the price of petroleum. The terms of this problem are such that it does not matter greatly whether the particular area under examination--in this case California--is in a better or worse position than the average, since a general shortage would influence prices everywhere by an amount considerably greater than typical inter-regional differentials.

The first impact of a general shortage of oil relative to demand will be, as indicated, a progressive rise in its price relative to the prices of other fuels and other products generally. This price rise, moreover, will not necessarily be moderate. In the case of a local shortage, such as that tentatively contemplated for California in the near future, price would rise no further than the import limit--that is, sufficiently to attract inshipments of oil from other areas. In the face of a general shortage, on the other hand, the general level of petroleum prices (as distinct from their inter-regional differentials) will be subject to no such limit and will proceed upward until total demand is curtailed and total supply expanded sufficiently that they come into balance. In what degrees will supply and demand be affected by such a price increase?

As argued previously, price increases--even large ones--offer no assurance of additional discoveries. Generally rising crude prices should intensify exploration and presumably result in some new discoveries; these in turn should

30 This estimate should be distinguished from various estimates of the "discovered plus probably discoverable" reserve in the world, which are often cited and which are in their essence highly conjectural.

augment supply and temporarily check the rise in price. In the long-run, however, such discoveries will only slow rather than check the development of a shortage. Price will continue upward. As it does so, will there then be no further source of additional supply other than discoveries, so that petroleum production will rather quickly dwindle to relative insignificance? This is apparently not the initial prospect, because there will apparently be a large secondary supply of oil in apparently "worked out" fields.

Petroleum production under methods currently in use is believed to recover only from a fourth to a third of the oil contained in the underground sands of a discovered field. Oil occurs in porous sands, in admixture with dissolved gas, and often fringed with water. It is generally contained under a pressure considerably above that of the atmosphere, so that when a well is drilled into a sand, oil flows to the well and, if the pressure is sufficient, out to the surface. The dissolved gases seeking release from such pressure sweep the heavier oil with them to the well-bottom; also, encroaching water pressure pushes oil into the well, and gravity flow adds its part. Currently used productive techniques simply exploit these natural forces in order to secure oil at the well-bottom. A well is drilled and thereafter as much oil is recovered as is driven to the surface by natural pressure or as can be pumped or otherwise lifted to the surface after it arrives at the well-bottom because of natural forces. That oil which natural conditions do not move as far as the well-bottom is left underground and not recovered. It is generally believed that when a field reaches the stage where oil can no longer be profitably produced by current methods, from 65 to 75 per cent of the original oil remains in the sands, lacking only pressure to bring it out at economic rates.[31]

Such oil is not, however, irretrievably lost. Methods have been tried and established for recovering a fairly large part of the remaining oil by secondary methods. These consist generally of "repressuring" the field with gas by forcing gas in through some of the wells, thus using an artificial "gas-drive", or in some cases by using a "water-drive" in similar fashion. Such methods have not been put in general use because of their high cost; their general application would apparently require at least doubling the present price of oil. But they are available, and a sufficiently high price of oil would bring them into wide use and greatly extend the available supply of oil.

A primary effect, therefore, of a general shortage and consequent large price increase for oil would be to bring forth a large additional supply at the new cost level. This might be sufficient to furnish an adequate supply on the new price plateau for a considerable period. It is estimated that California, for example, has a secondary reserve not recoverable by present methods of at least 27 billion barrels.[32] If even half of this could be recovered through repressuring techniques, there would be a California supply for 25 or more years of sufficient size to meet a greatly increased demand on the West Coast. The tapping of such supplies on a large scale, however, requires a much higher level of price, and this in turn introduces important additional considerations.

A first additional effect of a large price increase will be to stimulate greatly the development of substitutes for petroleum, or of substitute methods of securing its higher-valued yields, such as gasoline. A first alternative supply of hydrocarbon material which is likely to be tapped is found in oil shale deposits. There are very large deposits of oil shale in the Rocky

31 A. E. Dunstan (ed.) The Science of Petroleum (New York, 1938) Vol. 1, pp. 537-538, 577, 586, 590, 600.

32 E. E. Pyles, "Sources of California's Future Oil Supplies," Interstate Oil Compact Quarterly Bulletin, (Interstate Oil Compact Commission, Oklahoma City) Oct. 1943, pp. 17 ff. Mr. Pyles indicates that in addition to a higher price, unitized field operations would be a requisite for successful application of secondary recovery methods.

Mountain area, thought to be sufficient to produce 60 years' supply of oil at the present rate of consumption. This may apparently be made available at costs competitive with those of recovering petroleum by secondary methods. If results bear out predictions, there will be a very large supply of shale oil at the higher price level.[33] A second alternative source of supply may be the chemical industries, which are now quite able to convert vegetable material into gasoline (although at a currently prohibitive cost) and which may be able to effect a sufficiently economical process to add to the supply at prices competitive with those of secondary oil and shale oil.

There is thus likely to be no serious supply problem once the price of oil has risen sufficiently to bring forth secondary petroleum, shale oil, and chemically constructed hydrocarbons. If, as this situation develops, secondary oil recovery in California is able to compete with shale oil or other sources of supply, the life of the area as an important source of oil production should be greatly extended. The ability of the area to thus compete cannot be estimated with any certainty; all of the cost data upon which such estimates rest refer to situations which will emerge one or two decades hence. But there seems a strong possibility that exploitation of secondary recovery of oil will prove profitable in the face of competition from substitute sources, and in this event the long-run oil future of California is not unfavorable.

Even presuming the potential continuation of a large natural petroleum production in general and in the West, however, account must be taken of the impact of the requisite high price level on demand. Will demand remain sufficient at a doubled price to justify the continuation of a large scale industry?

With the presently established importance of the gasoline-using internal combustion engine, it seems probable, so far as we can predict at all, that the demand for gasoline will be largely sustained even at a substantially increased (perhaps doubled) price. Increasing gasoline prices would force the redesigning of engines to economize fuel, but with general economic expansion the aggregate demand for gasoline would be unlikely to decline in the net. This would be true in California or elsewhere where a market for gasoline is found.

The demand for fuel oil, on the other hand, would seem to be destined for a different course. During the great surplus era of the petroleum industry, from 1920 to date, crude oil prices have been low and fuel oil prices lower, with the result that fuel oil has been able to assume an important place as a cheap industrial fuel. In effect, it has been able to compete successfully with coal, our basic industrial fuel, and to supplant it in many instances. The availability of cheap fuel oil in California, for example, has put this state on some sort of a par with coal-producing regions as a supplier of heat and energy for industrial use. The ability of fuel oil to compete generally with coal, however, is strictly conditioned by its price; a doubling of its price would be sufficient to cause a large proportion of users to shift to coal if it were available, and, in many instances, to move toward coal supplies.[34]

A large general price rise for petroleum will presumably be accompanied by a proportionate or greater than proportionate increase in the price of fuel

33 See Lester C. Uren, "Our Oil Supply: Today and Tomorrow," California Monthly, April, 1944, pp. 9 ff., and "No Surplus," op. cit., May, 1944, pp. 21 ff.

34 This should be true for any industry for which fuel is an important element in cost, and includes cases both where the fuel is used to provide industrial heat and where it is converted into power. It should be noted that a growing oil shortage, leading to higher fuel oil prices, would presage an accompanying decline in natural gas production, thus eliminating the supplementary cheap fuel of an oil producing area.

oil, especially so far as the higher raw-material cost causes refiners to convert most of the crude into-higher-priced products. If this is the case, the demand for fuel oil will be severely curtailed, and the industrial use of petroleum will be supplanted by the use of coal, the resources of which are adequate, and by hydroelectric power.[35] As the price of petroleum rises, in short, the oil industry seems certain to decline as a source of cheap bulk industrial fuel and to become increasingly a gasoline, lubricant, and chemical industry.[36]

The implications of this potential development for oil economies like that of California are indeed considerable. Presuming a long-run continuance of oil production in the state at a substantially increased price level, it is conceivable that the demand would support a petroleum industry, on the present or a larger scale, which was devoted principally to gasoline production. The rise of fuel oil price to a level which was no longer reasonably competitive with coal or hydroelectric energy, on the other hand, would mean that the California petroleum industry would cease to provide a major attraction for industries depending in significant degree upon a cheap supply of industrial heat. Such a development would therefore provide a definite handicap to the maintenance or further attraction of industrial activity within California or Southern California. The long-run industrial future of the area would depend very strongly upon its ability to supply an alternative source of heat at an attractive price. Whether it will be able to do so, in view of its distance from good coal deposits, is a matter for conjecture. The considerable distance over which hydroelectric power must be transmitted to reach Los Angeles, moreover, is a long-run limitation on the ability of the area to supply an alternative source of power at an attractive price.

There is in any event a considerable interval for adaptation before a general shortage condition develops in oil. This interval, moreover, may be longer than conservative anticipation would have it. Both in California and in the world generally new oil discoveries may outrun expectations. It has been pointed out, for example, that in California there are several areas--the Sacramento Valley, the Salinas basin, and the Imperial Valley--in which intensive exploration may be rewarded by discoveries, possibly of major significance.[37] Similar potentialities exist elsewhere. Any prognoses of medium-run or long-run readjustments to local or general shortages of oil are therefore contingent upon risky conjectures about future discovery. Recognizing this, it nevertheless seems wise to take into account the potential consequences for the oil industry and for the economy of Southern California of possible alternative developments in the basic oil supply, and to condition plans and policies accordingly.

35 Hydroelectric power is a potentially economical substitute for fuel oil where direct power is desired, or where heat at very high temperatures is needed. But for ordinary industrial heat, as used in many lines of processing and manufacture, electric power is almost prohibitively expensive even at minimum rates, and if oil and natural gas were unavailable, a shift to coal would be indicated.

36 As indicated above, the production of natural gas would presumably also be dwindling under the postulated conditions.

37 E.E. Pyles, loc. cit.

SUMMARY

Such plans for the postwar period, it would appear from the foregoing analysis, should have three major objectives. First, anticipating an immediate postwar surplus of crude oil and refined products, they should provide for curtailing this surplus and for balancing immediate supply with demand without any demoralization of prices or glutting of the market. As indicated, the mechanics for accomplishing this end are already tried and established.

Second, recognizing the possibility of a progressive shortage of local oil supply relative to local demand, the plans in the first place should aim at maintaining local self-sufficiency for as long as possible, and in the second place should anticipate the impact on the California economy of an increasing dependence on oil imports. Short-term plans for general industrial development may be somewhat affected by this anticipation.

Finally, long-run plans should anticipate the impact of a general petroleum shortage, and of its primary result in the form of a much higher general level of oil prices. In an oil economy like that of Southern California this impact, though gradual, may be very large and may disturb the pre-established industrial structure of the area. Every attempt, therefore, should be made to anticipate this disturbance and to modify general economic planning in an appropriate manner.

THE OIL INDUSTRY AND POSTWAR REEMPLOYMENT

The foregoing paper has been concerned in the main with the immediate and longer-run postwar prospect for the Southern California petroleum industry, particularly as regards its ability to support various levels of industrial activity in California by providing, at attractive prices, the requisite supply of fuels. We have asked whether, given the other forces necessary to call forth various alternative levels of regional economic activity, our petroleum industry will be able to fulfill its essential role by providing the necessary fuel.

At the same time we have not inquired into the broader problem of what postwar level of economic activity the petroleum industry may be called upon to support--into the general issue of postwar reemployment on the Pacific Coast. Such an inquiry was in fact purposely avoided, as inappropriate to the scope of a paper concerned with one industry rather than with the whole economy.

Would it nevertheless be appropriate to attempt an appraisal of the petroleum industry's share in postwar reemployment--to predict how much income and employment we can count on from this industry alone? The answer is unfortunately negative. We cannot legitimately or logically arrive at a prospective figure for total employment after the war by constructing independent estimates for each of a number of individual industries and adding them together. This is especially true for industries like petroleum, which is not likely to support large quantities of net new investment activity, but is rather a supplier of materials to other industries and of final goods to consumers. The postwar output of such an industry, as indeed of industries generally, cannot be taken as independent of the outputs of all of the other industries which make up the economy. Rather the outputs of all industries must in logic be viewed as simultaneously determined within the interdependent economy of which they are parts. To predict future employment in any one industry we must take simultaneous account of all industries--that is, our analysis must deal with the economy as a whole and with the overall determinants of the level of production and employment.

In such an overall analysis, the petroleum industry will of course help to determine, or codetermine, the level of activity for the whole economy. Its most important influence on the overall solution is likely to stem from the relative abundance and prospective price of fuel oil and other petroleum-derived industrial fuels. In effect, the prospective supply conditions for petroleum in the postwar period constitute one of the important forces influencing the rate of industrial activity likely to be attained on the Pacific Coast. For this reason we have placed principal emphasis upon these supply conditions in the preceding paper.

But it does not follow that from an estimate of prospective supply conditions for petroleum we can directly derive a meaningful estimate of employment and income in the industry. This depends jointly upon the level of demand for petroleum, which in turn depends upon the future level of activity in aircraft

construction, ship building, agriculture, etc., all of which require extended analysis. In effect, then, the petroleum industry cannot be "counted on" for such and such a volume of employment and income independently of the rest of the economy. To suppose that it can is to mislead ourselves.

The main place of the petroleum industry is in any event not as a direct purveyor of employment opportunity (only 15,000 people were employed in producing and refining in the Los Angeles area before the war) but as a provider of fuel to basic industries. The emphasis of our main discussion has been chosen with this in mind, and we conclude with a final reminder of its importance.

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